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NOTES

OF

M. BERNARD'S

LECTURES ON THE BLOOD;

WITH AN APPENDIX.

BY

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TO

SAMUEL JACKSON, M.D.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE UNIVERSITY OF PENNSYLVANIA,

FOR HIS LOVE OF SCIENCE, AND THE QUALITIES OF HIS HEART,

This little Work

IS, BY PERMISSION,

RESPECTFULLY AND GRATEFULLY DEDICATED.

PREFACE.

The following pages contain the publication of notes taken at the lectures of M. Claude Bernard on the Blood, delivered at the College of France, in the winter of 1853–54. Much of what is comprised therein, is already known to the profession, but some is entirely new, and nowhere is the subject so complete, so connected.

As an Appendix, are added some notes, explanatory of the minute anatomy of the blood, of the bloodvessels, and of the parenchymatous organs more especially concerned in the circulation. These are derived from the lectures of M. Charles Robin, and from practical study under him.

This little work contains, then, "*the last word*" of French science at least, in regard to the anatomy and physiology of the circulatory system.

From a letter received from Professor Samuel Jackson, in answer to one asking his opinion as to the propriety of this publication, he has kindly permitted me to extract the following:—

"The project you mention meets my fullest approbation. The anatomy (using the expression, and adopting Robin's views) of the blood, its physiology and pathology, are the great questions and prominent subjects of interest and importance in medical science at this time.

"The sources from which you draw your information, MM. Bernard and Robin, are the most eminent living authorities in physiological science. You will be able to lay before us the whole of this subject posted up to the last moment.

"The views of M. Bernard on the Blood, I am

anxious to learn. My intercourse with him, though limited, inspired me with the highest respect for his abilities, and with entire confidence in his conscientiousness in prosecuting his experiments and inquiries. I have great reliance in his statements of facts; for he omits nothing, to eliminate from them all possible errors of observation."

In regard to the manner in which the work has been done, it is but fair to state that the notes were very faithfully and closely taken; and in their arrangement for the press, the phraseology has been so far retained as is compatible with an English form of expression. The French weights and measures have been preserved, as they are far more convenient than the English. It may be well, however, to state that a gramme is about equal to 16 grains avoirdupois, or to 0·0353 ounce exactly; and that a millimetre is about the one-twenty-fifth of an inch.

It is but proper to add, that both M. Robin and M. Bernard have assured me that they would see with pleasure the publication of these Notes.

WALTER FRANKLIN ATLEE, M.D.

PHILADELPHIA, September, 1854.

LECTURES ON THE BLOOD.

As a subject for his course of lectures, M. Bernard chose the Blood, as one of incontestable importance. The multitude of works, anatomical and physiological, which treat of the blood, make it very difficult to find anything new to say, yet if there are many facts acquired, there are many more unknown. It can be studied under many points of view, he will do so under one particularly physiological.

The mobility of the elements, of the principles of the blood, is very great, and they are incessantly undergoing regeneration. When this regeneration is slow, life is slow. When you take blood from an animal until he falls into a state of syncope, the day after he seems to have as much as he had before the operation. This, *the regeneration* of the blood, has been very little studied, and it is very important, for it holds under its control all the acts of the organism. The chemists have occupied themselves, it is true, with nutrition, but under another point of view. They, as, for instance, Lavoisier, who compared life to a lamp,

have proceeded in the examination of the phenomena as if they occurred in an apparatus that was burning, examining what entered and what came out. This examination is indispensable, for these things must be known, but it does not enable us to judge, or but very slightly, of the intermediary phenomena.

According to their experiments, in order to live, an animal must every day take in more than one-tenth of the weight of its body, as is seen in the following table. This experiment was made upon a cat not yet full grown. It is preferable to make it upon a dog or a cat; for the life of a bird is quicker than that of man, and that of a reptile is slower. For every 1,000 grains of weight in twenty-four hours, were taken in:—

Meat,	108·755
Water,	26·218
Oxygen,	29·478
Total,	164·451

And for same were given out:—

Urine,	91·036
In excrement and evaporated water,	55·069
Total,	146·105

18,346 grains remained then assimilated.

This other table is taken from experiments made upon birds:—

	Weight before.	Weight after.	Wheat eaten.	Time.
No. 1,	112·41	114·28	10·81	5 days.
No. 2,	119·79	117·07	10·68	4 days

As is seen, one has augmented in weight, the other has lost. These tables show us that what goes out of the body is not in correspondence with what enters, and that we cannot judge at all from these experiments of the intermediary phenomena that take place in the interior. We cannot tell if the difference comes from the old organism, or from substances that have been introduced. It is impossible to admit that aliments can enter at once into the circulation, without having undergone a change. Take the globules of the blood: most certainly they must be fabricated in the body, and the fibrine also. For the azotized parts there must be azote in the ingesta; but the azotized ingesta do not enter at once into the organism. These are the phenomena that will be most dwelt upon in the following pages; for in them must be sought the cause of profound alterations of the blood. In the change of the blood, all organs concur to a certain degree; but the influence of the liver, spleen, lungs, &c., is by far the most important. This study, then, of the regeneration of the blood, will, of necessity, bring in that of the organs.

The blood of carnivorous and herbivorous animals is about the same, yet their food is different. It is the organs that effect this, and to study properly the blood, it must be examined

before and after each organ. M. Bernard will commence by the blood of the portal veins, where the nutritive matters are taken in, and thence he will follow it through the series of metamorphoses it undergoes in order to maintain life. In this study, he will only advance facts, that he can demonstrate by experiments.

The blood thus studied, taken from such a point of view, cannot be defined. Blood is a nutritive liquid, but so is chyle; add that it is red, but still you would not have a definition. If arterial blood in all parts of the system can be considered as nearly identical, it is impossible to do so with venous. This surely cannot be looked upon as the same before and after its passage through the liver, or the spleen, or the lungs.

The great distinction of blood, as arterial, vital, red, and as venous, black, mortal, is not exact; for it is not mortal because it is black, nor vital because it is red. To show how small is the influence of color, and the nécessity of something else, M. Bernard introduced two sparrows under bell-glasses. The air under the one had been mingled with sulphurated hydrogen, in the proportion of 15 parts in a 100, under the other with one part of oxide of carbon. The two birds were instantly deprived of life, so that it could not be said they had been asphyxiated. When their bodies were opened, there was a very manifest difference indeed in the color of the blood, evident above all in the brain. In the one dead from the effect of the

oxide of carbon, the blood in the veins was red like that in the arteries. If, then, it be indispensable that venous blood become arterial, it is not less so that arterial become venous; for in the case where the venous blood was not produced in the capillaries, the death was as instantaneous as in the other.

Before entering upon the subject of the regeneration of the blood by digestion, M. Bernard thought it better to speak briefly of the general properties of *bloods*, at least of the most striking.

The color is red in all the vertebrated animals; in the invertebrated it is generally not, though some, as the leech, have red blood. In some it is blue, in the snail, for instance. Very little is known of the cause of the color in invertebrated animals; in the vertebrated, we know that it comes from the globules, which will be studied hereafter. In man, white blood and blue blood have been admitted. It never is perfectly white; but if drawn during digestion, when there is much chyle in circulation, it is whitish, resembling a mixture of blood and milk. This is particularly striking in animals, as, for instance, geese that are being fattened. In them the blood is whitish all the time, for it holds an emulsion of fats. A case of blue blood, the only observation known, is reported by a physician of the Hôtel Dieu. A woman, with a scorbutic affection, had hemorrhages from the nose and eyes, and the napkins were colored blue by the blood. Acids had no

effect upon the color, and alkalies destroyed it, properties belonging to Prussian blue.

The red color varies: that of women is said to be less red than that of men, of adults than of children, that of the cat to be clearer, of the ox darker, &c. Pregnancy gives, it is said, a darker tint. All these observations are given merely from "*vue d'œil*," and M. Bernard only gives them as he finds them reported.

Bichat explained the greater development of the superior parts of the fœtus, by their being supplied by red, arterial blood. Arterial blood does differ from the venous; but it is not the color that gives it the properties. The distinction in color does not exist in the fœtus; in it both bloods have exactly the same tint.

The bellies of animals have been opened and their young examined while still alive, and never is there any difference in the color. There is no doubt on this point; Muller at first said there was a slight difference, but afterwards he acknowledged his error. In adults a red blood and a black blood do exist, but there is red blood elsewhere than in the arteries. There is an organ whence the blood issues red—the kidney. With this exception, all have the property of changing the color. To observe this, the experiments must be made when the animal is fasting, so that there be no reflow of blood from the vena cava; at that time the artery and vein have no difference in color. In the rabbit there is a small vein from

the walls of the abdomen, emptying into the renal vein, and as its blood is dark it contrasts strongly with the other.

But of all changes in color, those caused by gases are the most interesting. M. Bernard will only call attention to the most important. In such experiments blood is generally taken from the animal and put under a glass containing gas; but we cannot know if similar changes would take place in the living animal, if the same changes would take place in the blood such as it is while circulating. The two principal gases experimented upon are oxygen and carbonic acid. The former is said to redden, the latter to blacken the blood. In the body the change of color in the lungs, and also that in the capillaries, are said to be owing to the properties of the two gases. The respiration of pure oxygen does not prevent the arterial blood from becoming venous; the blood in the veins is evidently more red than usual, yet there is still a very marked difference between its tint and that in the arteries. It renders the blood more red, but does not hinder it from becoming venous in its passage through the capillaries.

When an animal is placed in an atmosphere containing 30 per cent. carbonic acid, it dies, and upon examination the blood is found black in all the organs. This seems like a proof of what has been said that red blood excites life, while dark blood is injurious, and that these properties must be associated with these colors. But if we were to stop here, we would remain in error, for a red

color can come from gases excessively noxious. The oxide of carbon, a gas until now very little studied, renders the blood red to a very high degree, and it is one of the most deadly known. M. Bernard administered a very small quantity to a dog; the blood drawn from the jugular was of a bright red, and when it coagulated the color still persisted. This is worthy of attention; for though the blood is blackened by carbonic acid, yet it becomes more red again upon exposure to the air, and arterial blood under the same circumstances darkens. The oxide of carbon prevents any further change, and at the expiration of two or three days the color of the blood is found precisely the same. Sulphurated hydrogen blackens the blood, and it does not change afterwards, it remains the same.

This color of the blood has a certain importance in cases of poisoning by charcoal. In these cases it is never the carbonic acid that kills, for there is never 30 per cent. in the room; it is the carbonic oxide, of which but one per cent. in the atmosphere is fatal, that generally destroys life. M. Bernard showed this by destroying two birds; one in the mixture of carbonic acid, the other in that of carbonic oxide. On opening the bodies, the blood of one was very dark; that of the other everywhere red, as has been already explained. In cases where persons are killed by the vapor of charcoal, the blood is found red, except when death has taken place after their removal to an-

other air. If the blood be found black, the person has evidently been removed from the influence of the charcoal before life was extinguished.

What is the cause of this change of color? The coloring matter of the blood, residing in the globules, is one of its most important principles, for it is charged to take up certain gases, oxygen to carry in, and carbonic acid to carry out. It is thus ever changing, and each time a different color results. This difference of color has been explained by the different degrees of oxidation of the iron it contains. The similitude is somewhat correct, but evidently it is not thus the changes occur. Certain bodies are easily oxygenized; the globules are. This property can be arrested by certain substances. Prussic acid, mingled with a liquid in which the phenomena of oxidation are taking place, arrests them immediately. What is very remarkable, it has exactly the same effect upon the blood, so far as color is concerned, as carbonic oxide, and oxygen itself. Given to an animal, the blood is found red, and as when carbonic oxide is given, a further change in color is prevented. It seems as if the oxidizing property of the blood were at once arrested, the animal dying because he has no oxygen, his blood having lost the property of absorbing that gas. These facts are new.

The color of the blood is also influenced in other ways. When you bleed an animal to death from the large veins, the blood at first flows black;

but at last it issues red, and you find no distinction between it and that in the arteries. This is owing to the feebleness of the nervous system, whose influence is necessary in the capillaries, to change the blood from arterial to venous. When a limb is detached from the body, with the exception of the artery and vein, or for greater security these are cut also, and tubes are used to connect their extremities, the blood for a few moments returns black; but as soon as the nervous influence is extinguished, it returns red. What proves the necessity of the aid of the nerves, in the transformation of the blood, is the fact, that if the nerves be excited by galvanism, the returning blood becomes black again. It is not then always a good sign that blood be red. In fine, there are certain diseases where blood is red in the veins. M. Bernard said that in very grave typhoid fever, he had seen the blood in the veins not *rutilant*, it is true, but of a cherry color, so much redder than is natural, that when the vein was opened, he had at first supposed it to be arterial.

It has been said that the blood of every animal has an odor *sui generis*, and that this odor is changed by sex and by age. There is a smell in the blood, but it is very difficult to define what it is. This odor is said to be stronger in carnivorous than in herbivorous animals. When the blood is cooked, it is altogether different. It comes from an acid, and it has been asserted that the addition of sulphuric acid caused an increased

evolution by displacement. The odor of blood is in the serum and not in the globules. It is said, moreover, that it is not possessed by castrated animals.

The temperature of warm-blooded animals is nearly fixed, being scarcely influenced by changes in the surrounding medium; that of cold-blooded is very variable. It is not the same in all the warm-blooded; in birds, for instance, it is 3° or 4° (Centigrade) more elevated than in man. In man it is not the same in all parts of the body, as has been shown in a previous course of lectures; for the present, M. Bernard will only study it in the heart.

While at the extremities the temperature varies, for certainly it is lower in the fingers in winter than in summer, in the heart it is fixed. In the right ventricle it is higher than in the left. The contrary was long supposed to be the fact, from the experiments being made on the animal after death, when the heat was leaving the body, and the right ventricle being thinner than the left, of course it cools faster. The heart being withdrawn from the body, put a thermometer in each ventricle and place the organ in water at 40° Centig., the thermometer will stand at 40° also; then remove it and leave it in a temperature of 16°, and in a short time there will be a difference of 6° in the two instruments. The difference of temperature then noted by these experiments was not owing to a difference previously existing in the blood. M. Bernard last summer experimented

upon at least a dozen animals while yet alive, the instruments being passed into the brachio-cephalic artery and into the descending vena cava. The same thermometer was used, for fear of the possibility of a slight difference in instruments, and the experiment was varied in every possible way. The temperature was always higher in the right ventricle, where it was 39° or 40°. The difference (and the thermometer used was graduated to the hundredth of a degree) was never more than one-half or one-third of a degree. As will be seen hereafter, the maximum of temperature is in the portal vein. This diminution of temperature is owing to the air, which cools the blood; when it does so in the fingers, why should it not do so in the lungs. M. Bernard has made his experiments in the summer, when the weather was very warm, and will repeat them in order to see if there be a diminution, proportionate to the temperature of the air. To resume; the blood of mammiferous animals is warmer in the veins than in the arteries; in the portal vein, than in the aorta.

When M. Bernard said that warm-blooded animals could be placed in cold or warmth without any sensible variation of temperature, of course he spoke of conditions in which life can continue. When an animal is placed in a very hot atmosphere, the change is scarcely sensible, and yet the blood is modified, and in a way very fatal to life. Magendie's experiments are very interesting. They show that an animal confined in an atmo-

sphere, remember without vapor, of 66° or 80° Centigrade, at first seems to suffer very little; but that at the end of some time, of two or three hours, the blood is heated, and he dies, so to speak, suddenly. If a thermometer be plunged in this blood, it will be found in reality hotter than before; but not much, never more than four or five degrees. The blood of warm-blooded animals, then, can change in temperature; but in a very limited manner.

The temperature being changed, other and important changes occur,—the blood becomes black, and does not redden on exposure to the air. When, in place of a mammiferous animal, the experiment is tried upon a bird, whose temperature is 44°, just the fatal temperature of the former, the same thing is observed; the animal dies when its temperature is increased four or five degrees. The muscular contractibility of these animals is lost just at those temperatures, as is seen by plunging them in water heated to that point. In these experiments they are *bathed* by blood heated to that degree, and that alone suffices to explain the sudden death. Only physiological conditions are spoken of in this place; others, pathological, that cause the temperature to vary, will be spoken of hereafter.

The quantity of blood in an animal has been sought after in various ways. The first was to open a vein and weigh what issued,—a vicious method, for it can only indicate how much an

animal must lose to die. It shows, however, they die before much be lost—when about the twentieth of that contained in the system. When an artery is opened, a much greater quantity of blood is obtained than when the heart is directly opened; for there is a reparation of the blood, and you do not have the quantity existing in the animal at a given moment. Another observation has been made by butchers, that when the animal has been previously knocked on the head, he loses much more blood than when this has not been done; the commotion of the nervous system having so acted on the capillaries that they empty themselves better. It has been suggested also to calculate the quantity of blood from that of the iron; the proportion of iron, existing in a certain quantity of blood being known, the animal was burned, and all the iron being separated from the ashes, the calculation was readily made. This is, perhaps, the most exact way; but is there no other substance in the economy containing iron? The hair alone, besides the blood-globules, contains a notable quantity, hence previous to the burning, the animal must be shaved. M. Bernard said, with a smile, that chlorotic patients, having generally a very fine head of hair, some physicians have pretended that it was the cause of their affection, the iron being taken there in place of supplying the blood globules. In the coloring matter of the bile, there is some iron, and Berzelius, as is known, thought it came from the destruction

of the globules. In no other part of the organism is there any iron found. The proceeding of Valentin for calculating the quantity is very ingenious, and if not exact, it is not the fault of the author. He took some blood from an animal, heated it, and noted the water which was given off, and the residue which remained. A quantity of water, equal to the blood extracted, was injected, and afterwards the animal was again bled, and the water and the residue observed as before. The blood of the second bleeding holds more water than that of the first, and thus the whole mass of blood can be calculated. There is, however, this objection to be made, namely, that the water injected has not been uniformly divided throughout the mass of blood, as can easily be determined by drawing blood from different veins, you will find different proportions of water. When an excess of water is injected into the system, and the animal killed, it will be found located in certain organs; the liver and the spleen, and after them the lungs, charge themselves with the excess. By Valentin's method, very nearly the true result is arrived at, and the following table given by him is about correct: In the dog—the blood : the weight of the body :: $1 : 4\frac{1}{2}$; in the cat, as $1 : 5\frac{1}{2}$; in the rabbit, as $1 : 6\frac{1}{4}$; in the sheep, as $1 : 5$. A horse, weighing fifty or sixty kilogrammes, died when he had lost from fifteen to twenty of blood. Experiments have not been made on man; but judging from those on other animals, the quantity of blood, in

a man weighing 145 pounds, would be 32 pounds. This is much more than has been said, when, judging from mortal hemorrhages, seven or eight pounds have been given as the weight of the blood.

The quantity of blood augments at each moment of digestion, as is proved by the rising of the mercury in a barometer attached to an artery, for the tension of the vessels depends upon the quantity of blood contained in them. At the same time the liver and the spleen swell, and are only made to diminish by secretion from the lungs and the kidneys. In fasting, an animal consumes his blood, and dies just as in hemorrhage. Abstinence, then, is a cause of diminution in the quantity of blood. If, instead of being completely deprived of food there be only a temporary deprivation of blood by bleeding, as for instance by small bleedings repeated every day for six weeks, at the end of that time there will be a considerable hypertrophy of the heart. This is explained by the action of the heart. Normally, the pressure of the blood in the arteries raises a column of mercury 140 millimetres, and each impulse of the heart raises 10 millimetres more. After repeated bleedings this tension of the arteries diminishes so as to be but 100 mill., and in proportion as it decreases does the impulse of the heart increase. Under this influence the heart is hypertrophied; above all, the left ventricle. When on the contrary the vascular system is too full, the impulse

of the heart is very small. In Magendie's experiment, where, by injecting the blood of one dog into another, he might be considered to have doubled the quantity in the latter, the contractions of the heart, in place of being 10, were but 2 millimetres.

PHYSICAL PROPERTIES OF BLOOD.

It is very important to know the *nature* of a liquid, when its circulation is being considered. Blood is a viscous, albuminous liquid, differing thus from pure water, charged with salts, and containing corpuscles. It is, then, a liquid more or less viscous, holding insoluble parts in suspension. A viscous liquid circulates better in the capillaries than water, and the blood circulates with more difficulty as it becomes less viscous. Inject water into the kidneys by the renal artery, it will come out by the vein; but very soon the tissue of the organ is infiltrated, and at last the circulation is entirely broken. If in place of water, serum of blood be injected, it will pass into the vein, and none will be infiltrated, because it contains albumen. Besides the albumen, the blood contains globules that are heavier, and also fibrine that is lighter than the blood. In order that the globules can circulate, the existence of fibrine is necessary. When you inject serum containing globules, or when the blood is defibrinized and the part is examined under a micro-

scope, the globules are seen to be all at the bottom of the vessels, and at last the small vascular ramifications are blocked. The fibrine of the blood then keeps the globules from falling to the lowest part of the vessels; lighter than they are, it surrounds, envelops, and separates them. When a cup is filled with blood, if after the coagulation successive slices be examined, the upper will be found to contain fewer globules than the lower; and should the coagulation be very slow, there will be on the top a slice of fibrine entirely deprived of globules. The following experiment of M. Poiseuille shows very well the effect of the addition of globules upon the circulation of serum. The instrument is a bowl of the capacity of 6 cubic centimetres, communicating directly at the bottom with a tube the 10th of a millimetre in diameter and 110 millimetres long. The bowl filled with serum emptied itself in 20′ 33″; when with serum and globules in 68′ 47″. It cannot be said that the globules could not pass, for the diameter of the tube is much greater than that of the capillaries. When the serum alone was used, the jet was continuous; with the globules, it was never entirely interrupted, but it was in jerks.

The rapidity of the circulation is influenced by the addition of an acid, or an alkali. In the living animal, the blood is always alkaline. In blood abstracted from the body you can very easily make the alkalinity to disappear by the addition of an acid; but when in the living animal it is attempted

to add enough acid to saturate the alkalies, he dies long before it is effected. Of course the acid injected is one having no toxic action. When in the instrument just mentioned, the serum of an ox was used at a temperature of 10° Centigrade, it flowed away in 1048 seconds. When ammonia was added, it emptied itself in 981; when acetic acid was used until the reaction of the serum was neutral, in 1070; when tartaric acid, in 1233 seconds. The nitrate of potash hastened the flow. Alcohol in the proportion of 4 per cent. retarded it, it required with it 1223 seconds. In all the experiments, then, made to show the influence of acids and of alkalies on the circulation, it is invariably found that acids retard and alkalies hasten it. Ammonia and potash accelerate the flow more than soda.

The albumen contained in the blood has a very great influence upon it. There are many substances in solution in the blood that should not be so in an alkaline liquid. When copper is introduced, it circulates; and how is this, when, as M. Bernard showed by the effect of potash on a solution of sulphate of copper, an alkali in the liquid causes its precipitation? It is the presence of the albumen that causes this difference in the action; it has this property, of rendering metallic substances soluble. These substances, after circulating, finish by being deposited in some organ. Silex placed in a solution of sugar, is slowly dissolved; destroy the sugar in the solution by the

addition of yeast, and the silex is immediately deposited. The same action takes place in the economy, and the deposition of certain substances in certain organs rather than others is thus explained. When the principle enabling it to be dissolved is made use of or destroyed, it is at once deposited. We know that arsenic and antimony, dissolved in the intestines and carried into the system, are located in certain organs. Suppose that it be the presence of albumen that causes the solution of the antimony, as a certain quantity of albumen is destroyed in the liver, the antimony would be found there deposited. In the blood some substances have their chemical actions entirely masked. When some lactate of iron in solution is dropped into water, and then the cyanuret of potassium added, prussic blue is formed. If it is dropped into serum, a kind of combination is produced between the iron and the albumen, so that the blue is not formed by the addition of the cyanuret. If, however, an energetic acid that will destroy the albumen be added, the color will at once be formed. M. Bernard made many experiments to show this, upon the living animal. When the cyanuret and the lactate were injected into the jugular vein, Prussian blue was never formed in the blood; but when the substances passed out in the urine, or into the intestines, when the albumen had been destroyed, a magnificent Prussian blue was formed. Two substances,

harmless in themselves, might thus in the body form a toxic substance, and prove fatal.

The phenomenon of catalysis, on the contrary, takes place in the blood with the greatest facility. If with sugar and yeast you try to produce fermentation in the blood, it takes place perfectly well. Emulsine and amygdaline when separated are not venomous, mix them and prussic acid is formed. In the vein of an animal, M. Bernard injected emulsine, in that of another, amygdaline, and no harm resulted; when however he injected the other in either of the animals, it died as if struck with lightning. . When sugar and yeast were injected, in some cases carbonic acid was so rapidly produced that it could not be dissolved in the blood, and the animal died as if air had been thrown into the veins; in others the animal was intoxicated by the alcohol formed. Blood then does not oppose itself to the phenomenon of fermentation.

All the principles of the blood are *fugitive*, so to speak, some more so than others. Each principle has its use, its action, and is destroyed when the function has been performed. Thus the globules are for the purpose of introducing gases, and this accomplished they die. Sugar, also, and albumen have their functions; and these accomplished they are destroyed, and must be renewed. These phenomena are like those of fermentation. Microscopically examined, the blood is seen to carry particles held in suspension. These are the

globules, red and white, and the globulins; there are also very small particles of fatty matter. Bubbles of air have been seen; and small animalcules have also been detected, and these do not indicate a sickly condition.

The red globules are the most important of these particles. Their discovery is generally given to Malpighi, in 1672; but M. Dumesnil maintains that they were discovered five years previously in the frog. These red globules are innumerable. Let three or four drops of blood fall into a quart of water, and you will find them everywhere. In a mass they have a red color. They are only found in vertebrated animals, and when they are abstracted the blood is transparent, colorless. Invertebrated animals have no red globules; and some have red blood, as leeches and earthworms. When their blood is examined it is seen that it is the liquor of the blood that is red; globules do exist in them, but they are not at all red —they have an analogy with the white globules of the vertebrated animals. Their form in animals is not always the same, they are sometimes round, sometimes oblong; these are the two principal forms. The form of the globules distinguishes the animal. In the mammiferous, with the exception of the camel, the dromedary, and the alpaca, they are rounded. Birds, reptiles, and fish have them ovoid. In some fish they are rounded, but the exceptions are very rare.

The volume varies, and, to a certain point, can

distinguish the animal. It can vary in the same animal, in different individuals, and in different species. In the mammals the largest is that of an African monkey, $\frac{1}{120}$ of a millimetre. In man it is $\frac{1}{150}$, and it is the same in the dog, the rabbit, &c. In the cat it is $\frac{1}{171}$, in the sheep and the horse $\frac{1}{200}$. The goat has the smallest, $\frac{1}{285}$. In frogs and birds they are larger than in the mammiferous animals. Fish and reptiles have them much larger. In the frog they are $\frac{1}{37}$ of a millimetre, broad, and $\frac{1}{75}$ long. Their structure is very different. For a long time they were considered to be membranous cells, containing a liquid substance, and some iron. The appearance of a nucleus is false, being owing to an excavation. Their intimate structure is not yet settled. They easily dissolve in some substances, and the coloring matter is shown not to be on the surface. In some apoplectic effusions, the coloring matter comes out, and crystallizes in the neighborhood, and yet the globules preserve their form perfectly. In reptiles there is a nucleus, and by placing the globules in acetic acid, it is rendered free by the dissolution of the exterior envelop. The nucleus does not, however, belong to the oblong globules, that is to say, it does not belong to their form, for birds have none. It seems to characterize animals with cold blood.

It has been said that the form of the globule gave special properties. Magendie injected the blood of birds, having oblong globules, into mammiferous animals that have round; but he only

found that they disappeared, he could never discover them again. The round globules are smaller, and as the diameter of the capillaries is in relation to the size of the globules, it was thought the oblong would be arrested in the lungs; but he never could find any after his injections, which were made into the jugular vein.

In the fœtus, it is said, the globules are round as in the adult, and with a true nucleus. The blood of the fœtus has, in a much less degree than that of the adult, the property of absorbing oxygen. The globules of the fœtus are much larger than those of the mother, which is an argument against the passage of the blood of the mother to the fœtus.

In the fœtus of birds, also, the globules descend, taking the characters of those of mammiferous animals, just as those of the latter descend, and take that of reptiles. The form changes after the death of the animal, and also after being removed from it, and placed under the microscope. It becomes deformed, *shagreened.* Experiments have been made to show this to be a sign of death; but it has been seen in persons still alive, above all in cases of cholera. M. Bernard does not know whether it should be considered as a fatal sign; but it most surely can exist during life.

The white globules are much less numerous than the red. They exist in vertebrated animals, and, according to some, in invertebrated. They are very easy to distinguish from the red by their

color, their greater diameter, their roundness, and the absence of the appearance of a nucleus.

Their appearance, under the microscope, is peculiar; the red move about, while the white are stationary, and form obstacles by which the movement of the others is arrested. A very interesting characteristic is this: under the microscope they fix themselves, as was just said, against the glass, and, after a time, prolongations form from the surface, very slowly and successively, which may afterwards disappear by re-entering. These prolongations form at the moment of the withdrawal of the blood, and last, in mammiferous animals, one or two hours. In summer they last but half an hour. When the globule remains quiet for five minutes, there is no more change—it is dead.

In the invertebrated animal, there are no red globules; but there are white ones, or some undergoing similar changes. The white globules have also been seen in the foot of the frog while living. They are seen to stick against, to attach themselves to the walls of the vessels. This is similar to what takes place in the small infusoria—a kind of gelatinous animals observed in animal liquids. These are sometimes round, at others rounded, at others with prolongations, by means of which they are even able to move themselves. Such movements are those of vitality, they are those of a living object. In some cases there is an exaggerated production of these white globules. It

constitutes a disease, coinciding with affections of the spleen, or of the glandular bodies. M. Bernard called attention particularly to this kind of vitality or of mobility. To a certain point, he declared, it could be said that the globules were living.

The globulins are small, rounded bodies, found in the blood, much smaller in diameter than the red or white globules. They exist in different quantities according to the condition of the animal, but in greatest abundance at the moment of digestion. It has hence been said that they were chyle; but we know that chyle is only found when fatty substances are taken up, and the globulins are found no matter what may have been ingested. From their constant existence and their greater abundance at the time of digestion, they have been supposed to be the first condition of the formation of globules. The same globulin has never been followed; but all the intermediary stages have been observed in the frog. They are interesting as being the origin of the globules, and as existing at the moment of digestion.

Certain animalculæ, called hematozoa, have been discovered in the blood, and eleven or twelve different kinds have been signalized. They are generally infusoria; but some have a more advanced organization. Some have been said to be characteristic of certain affections, as some mental diseases, and syphilis; but all this is very vague. Again, M. Rayer, in certain aneurisms, has noticed

a worm—the strongylus. In a dilatation of the iliac artery of a horse, a great quantity have been found. Another kind has been found in the sinus of the brain of the dolphin. In the dog a certain species is often found circulating, while the animal is perfectly healthy. In the rat, a filiform worm is found. In the frog many kinds are found; it is one of the animals containing the most infusoria. Some are found in the heart of certain molluscs. These are the principal already described. No idea can be formed as to the part they play in the economy; some, indeed, as the *strongylus* in aneurisms, must be considered as morbid, but some of the others cannot be.*

When the blood is withdrawn from the body, two very interesting phenomena take place,—the crystallization and the coagulation. The crystallization of the blood, observed by Otto Funke, is a very singular phenomenon. He took a drop of blood from the splenic vein, and leaving it under the microscope, between two pieces of glass, when nearly dry, a red crystal was formed. At first, the phenomenon was thought to be peculiar to the blood from the spleen, but the experiments being multiplied, it was seen that blood from any part of the body can crystallize. When a drop of water is added, it takes place more easily. It has been said that the form of the crystal was special to the animal, but it can be modified by certain circumstances. The globules

* See Appendix, Note A.

disappear; when, as in cold-blooded animals, they contain a nucleus, this nucleus remains. When the crystals are made to form as large as possible, and examined, they are found to contain a great quantity of iron. Their composition is the same as that of the globules. They dissolve in water, at 40° or 45° Centigrade, but not at all in cold water.

This phenomenon takes place as soon as the blood is drawn away, but M. Bernard has observed it in the blood of a dog, that had been put aside for more than a month. The phenomenon is crystallization of the globule.

The coagulation of the blood commences at once on its withdrawal from the body. In warm-blooded animals it is finished more quickly than in others, and in birds sooner than in mammiferous. Arterial blood generally coagulates better than venous. Some venous blood scarcely coagulates at all, as that of the renal vein, a fact observed by Simon, who says that it contains no fibrine.

In some circumstances the blood coagulates with great difficulty, as after certain poisons, and in animals exhausted by fatigue; and cold produces the same effect. If an animal be made to die slowly by cold, and just before death some blood be taken, it will scarcely coagulate. M. Bernard does not know what becomes of the fibrine in these cases, but notices the fact. When blood is taken from cold-blooded animals in the winter, it coagulates with great difficulty, and

sometimes not at all; when taken in the summer it coagulates perfectly.

M. Bernard thinks that this coagulability is connected with the respiration, with the animal temperature; that it is proportionate to the elevation of temperature, as is shown by observations on birds, mammiferous animals, &c., and also, that in the individual, it is influenced by cold. The blood coagulates in some morbid circumstances. When there is inflammation of the vessels, there is coagulation of the blood, whether it be in an artery or a vein, at the level of the inflamed part. Tie an artery for aneurism, there is a clot below the ligature, although there be no stagnation of blood, from the inflammation of the vessel. What is this phenomenon of coagulation? It is certainly a solidification of the fibrine. It always takes place when the blood is withdrawn from the body, and although it be maintained at the same temperature it still occurs. The fibrine separates from the serum, and holds the globules imprisoned. The mass is heavier than the serum, and falls to the bottom. This greater weight does not come from the fibrine, which alone tends to float on the surface, but from the globules. From this tendency of the globules to fall, and of the fibrine to rise, the composition of the mass will not be the same in all its parts, the globules must be much more numerous at the bottom. If the coagulation be slow, the deposition of the globules can take place to such an extent, that a white clot

will be seen on the top. This takes place above all in the horse, where the coagulation is very slow. In birds, where it is very rapid, it is not seen.

Sometimes a white coat is formed on the surface of the coagulated blood, dependent upon certain conditions of the animal in regard to digestion. If the blood be taken when there is chyle in the circulation, the surface of the clot will be of a milky whiteness, and the serum itself will be whitish. The chyle is lighter than the globules, and again the blood of animals coagulates more slowly during full digestion. The white layer, the buffy coat, does not then belong peculiarly to a morbid condition.

Sometimes there is a whitish coat, that is not owing to this, but to a superabundance of white globules. It has been said also that it is seen in the blood of the spleen from the circumstance of a very great quantity existing there.

The fibrine of the clot has not always the same appearance. Bleed an animal very often, each time removing the fibrine from what you have withdrawn, and injecting again the rest, the nourishment continuing the same as before the experiment, the strange fact will be observed, that the quantity of fibrine goes on increasing. M. Magendie, who made the trial, said that this was the cause of finding more fibrine in cases of inflammation because they were treated by bloodlettings. But this fibrine is not the same as the normal; the fibres are shorter; you cannot draw

it out, it is not so elastic, and if the bleedings be repeated very often, it becomes like *papier mâché*. It only then resembles fibrine, in its separating from the rest of the blood. When it is taken and left for twenty-four hours in water at 40° or 45° Centigrade, it is all dissolved, and if the water be examined it has all the characters of an albuminous solution. This goes to support the idea that fibrine is only transformed albumen. M. Magendie has distinguished these two forms of fibrine, calling the latter pseudo-fibrine.

The blood does not vary much, whatever be the food, and as it is the principle of the secretions, this is necessary. The variations in the blood, and their causes will now be examined. The first thing to do, is to separate its different constituents. Once out of the veins, it separates of itself into two parts, serum and the coagulum, which contains fibrine and globules. If, instead of allowing it to take place thus, the coagulum be made to separate into fibrine and globules, there will be to be examined, serum, fibrine, and globules, as parts into which the blood spontaneously separates, on its withdrawal from the body. Serum is a liquid, not red as the blood, but of a citron yellow color, alkaline, and containing in solution a certain number of substances, both organic and inorganic. The normal, ordinary condition of course is here spoken of. Some of these substances are *fixed*, that is to say, are always there, and in about the same proportion: others are only there in order

to be eliminated, or to be changed into other substances; their existence is always fugitive. The latter, the *fugitive*, will first be described.

Uric acid and urea, are only found in the serum, never in the clot. They are completely dissolved, and their proportion is so very feeble, that it is only recently that they have been found to exist constantly. The kidneys are incessantly engaged in eliminating them from the blood, but still some can be detected in about six pounds. In the blood of the ox some hippuric acid is also found, which is likewise eliminated by the kidneys. These substances may possibly exist in very great abundance, for instance, in some cases of disease of the kidneys, or of their extraction, when they have been detected in a very small quantity of blood, not more than a hundred grammes. A singular fact noticed after the removal of the kidneys is this. In twenty-four hours about six grammes of urea and uric acid are produced in an animal, and yet if you bleed at the end of twenty-four hours after the operation, you will still find them to be in very feeble proportion in the blood. Where is it eliminated in these early times of the operation? It is in the intestines, and particularly in the gastric juice, as a fistula in the stomach of a dog enabled M. Bernard to demonstrate. Before the operation there was none in what issued from the opening, and immediately after there was. After remaining some time in the intestine, the urea changed into ammoniacal salts, and what is

strange, the gastric juice continued all the time to be secreted. When substances generally eliminated by the kidneys were injected into the blood, they were found in the stomach. In lower animals, where there is no kidney, it is thus the elimination always takes place. This operation does not much enfeeble the animal. He vomits, and has diarrhœa, and at last, when enfeebled from not eating, he becomes sick. At this time the urea is no longer eliminated by the intestine, and you find much in the blood. And thus, in individuals affected with disease of the kidneys, you often see vomitings and derangement of digestion, owing to the urea being thrown into the intestines, and there undergoing change into ammoniacal products. In diabetes you find very little urea in the urine, and M. Sigalas gave urea to such patients in the expectation of finding it there, but he did not find the quantity to be increased; it was transformed into ammoniacal products.

Another temporary product is carbonic acid, which is being constantly thrown off by the lungs, as urea, &c., are by the kidneys.

SUGAR.

This product was known to exist in the urine of diabetic patients. M. Buchardat showed it to exist in such cases in the blood, and supposed it to be there only in abnormal conditions. Some

years ago, M. Magendie published a work on the normal existence of sugar in the blood. His conclusion was that it existed there normally, but he supposed that it always came from sugar introduced from the exterior. Making experiments, M. Bernard was led to see that it did not come from the aliment, that it was not accidental, but that it was the product of a certain organ. The sugar does not exist in the clot, and it is destined to be eliminated, not as sugar, but as carbonic acid. In the organism there are two phenomena, the production and the destruction of sugar; the liver is for the former, and the lungs for the latter. The lower vena cava conveys the sugar from one organ to the other, taking it to the right heart from the liver. If experimenters had bled in the lower vena cava, sugar would long ago have been found in the normal blood.

When but little sugar is made, all is destroyed in traversing the lungs. There is an intermediate state of the sugar, namely lactic acid, when more is formed, as in digestion. When too much is formed it is not changed into lactic acid, but is carried into the arterial system, and thence into the venous. Hence, if a man be bled when digestion is going on, you find sugar in the veins of the arm, and never when he is fasting. There is then an oscillation in the production of sugar. The blood must not contain more than one part in a hundred of sugar; when it contains more

than that it passes off by the urine, and the patient can become for the moment diabetic. At the commencement of diabetes, and also when recovery is taking place, sugar is only found during digestion. Of course all the intermediate products between sugar and carbonic acid are to be found in the blood. These are the variable principles found in the blood.

The following analysis is of the venous blood. Remember, that the blood which we are considering is that of the living animal, when the globules are the solid parts, and the fibrine is in solution. The quantity of water is determined by the weight before and after drying. To make a just calculation, the blood must not immediately be put into a large vase, but, according to M. Lecomte, should previously be enclosed in a phial. When this is done you find some to evaporate, and to be condensed, on the bottle above. This condensed vapor is said to contain the odor before spoken of, which is to be perceived upon the addition of sulphuric acid.

Blood-globules.		Liquid.	
Water,	688·00		902·90
Solid matters,	312·00		97·10
Hematine,	16 75	Fibrine,	4·05
Globuline,	282·22	Albumen,	78·84
Fatty matters,	2·31		1·72
Extractive matters,	2·60		3·94
Mineral substances, &c.,	8·12	Min'l substances, &c.,	8·55
	312·00		97·10

	Blood-globules.		Liquid.	
Chlorine,	1·686		3·644	
Sulphuric acid,	0·066		0·115	
Phosphoric,	1·134		0·191	
Potassa,	3·328		0·323	
Soda,	1·052		3·341	
Oxygen,	0·667		0·403	
Phosphate of lime,	0·114		0·311	
Phosphate of magnesia,	0·073		0·222	
		8·120		8·550

The albuminoid matters are divided into oxalmine and anoxalmine; the former do not change color by the addition of hydrochloric acid, the latter take a violet hue. Hematine and globuline are special to the globules. Hematine is the special coloring matter of the blood. It is always found together with iron, from which it can be separated without losing color, but it no longer possesses the power of absorbing oxygen. It exists particularly in the interior of the globules.

The globuline is chiefly in the exterior, and is colorless. These two principles are easily separated; by uniting the corpuscles with alcohol and a little carbonate of soda, and then adding ether, the globuline is deposited. The same principle, globuline, is found in the crystalline of the eye.

Many chemists consider these two substances dissolved within the cell. When the globules are left in water, they swell and the coloring matter comes out, leaving the globules colorless. In a physiological state, this coloring matter of the corpuscles is not dissolved in the serum of blood, but it takes place pathologically.

Two principles analogous to these in the fluid portion of the blood, are fibrine and albumen. They are easily distinguished in the blood, by the action of nitric acid and heat. They have long been considered as bodies of the same kind, under the name of albuminoid, and they can in fact, be transformed one into the other.

Caseine and gelatine have been declared to exist in the blood.

Caseine has been of late the subject of special researches, and is said by some to be more abundant in the blood of nursing women.

In these experiments all the albumen of the blood is removed by heat, and the liquid left treated by nitric acid, all that then coagulates is considered to be caseine; for caseine, as every one knows, from milk, does not coagulate by boiling, the addition of an acid being the only thing causing it to coagulate at that time. This presence of caseine, during the time of lactation, had a certain significance; for it has been maintained that all secreted substances are first found in the blood. That "all the principles of the secretions are found in the blood," is true in a general way, but not absolutely so. Pancreatic juice cannot be found in the blood, nor can that of the stomach; not a trace of pepsine can be detected in the circulation. Those substances, that are excretions, that have played their part, and must be thrown off, these are found; but those that are again used are not.

A good characteristic by which to find caseine is its precipitation by the sulphate of magnesia. Sulphate of soda does not coagulate it. Take the serum of the blood, treat it by the sulphate of magnesia, and you have no precipitate, and as the salt has this special property, you may judge that no caseine exists there. Caseine is a substance totally different from an excretion.

Colostrum differs from milk in containing much more albumen. In milk the caseine takes its place; but the albumen never entirely disappears from the milk. Colostrum is found in the mammary glands of animals about to bring forth. The character of gelatine is this, that it dissolves by heat, and coagulates by cold. There is an analogous matter found in the blood, when withdrawn from the body; but whether originally existing, or formed after its extraction is doubtful. The question in regard to the existence of these two bodies, is a very difficult one; that there are two bodies very analogous is most certain, but whether they are really gelatine and caseine, M. Bernard declared he could not say.

All these albuminoid bodies, treated by crystallizable acetic acid, separate into two parts, one dissolving and the other not. The one not dissolved is fibrillar, the other, when thrown down from its solution by potash, is globular. By the action of hydrochloric acid one is colored violet, and the other not.

The fats are of two kinds, those in suspension,

and those in solution. Pancreatic juice has the property of forming with them an emulsion, and they are thus carried into the circulation. When no fatty matters are eaten by the animal, they are still found in the blood in minutely divided globules. M. Bernard has found it thus in animals who had not eaten anything for eight days. Does this fat come from the fat of the body? Most probably it does; for it disappears when the animal does not eat. Independently of the fat in suspension, there are others saponified, and these are always combined with phosphorus. It is thus found more particularly in certain organs, as in the brain. The analogy between the brain and the liver, by chemical analysis, is very singular; they are the only two that contain these combinations of fats with phosphorus—the oleo-phosphates.

M. Bernard only treated extractive matters with a shrug of the shoulders, as matters *not determined.* There are, besides, in the blood inorganic matters, and, what is singular, they are in about the same proportion in both the solid and the liquid parts, except iron, which, as will be seen, has a special affinity for the globules. Potash and soda exist in very great proportion, in a state of solution, in both the plasma and the globules. Potash is chiefly in the globules; soda in the plasma or serum. This special localization of these two alkalies in the blood, shows a physiological difference in the two salts. There is a great difference in the proportion of these two alkalies in different

animals; very great between the carnivorous and the herbivorous; and in this relation man approaches more to the one class than the other.

The chlorides are abundant. There is a difference in them also; for they exist especially in the serum, and in feeble quantity in the globules. In man there are 21 parts in 100 in the globules, and in the plasma 40·68. In all animals this is true.

THE PHOSPHATES AND SULPHATES.

The phosphates have been the object of particular study. They exist chiefly in the globules, being much more abundant than in the plasma. The quantity of phosphates is proportionate to the rank of the animal in the scale of being, and in the same species a much less quantity is found in the sick and feeble. This would seem to show that they are there for some other purpose than the formation of bone. As a considerable quantity is always in the blood, it must be there for some object. That in the globules is chiefly in the condition of phosphate of potash; the little found in the serum is probably phosphate of lime or of magnesia.

The following tables show the proportion of these substances in a hundred parts of inorganized matter:—

	GLOBULES.		PLASMA.	
	Potash.	Soda.	Potash.	Soda.
Man, . .	40·89	9·70	5·19	37·74
Dog, . .	6·07	36·17	3·25	39·68
Cat, . .	7·85	25·02	5·17	37·64
Sheep, .	14·57	38·07	6·56	38·56
Goat, . .	37·41	14·98	3·55	37·89

	GLOBULES.		PLASMA.	
	Phosphoric Acid.	Chlorine.	Phos. Acid.	Chlorine.
Man, . .	17·64	21·00	6·08	40·68
Dog, . . .	22·12	24·88	6·65	37·31
Cat, . .	13·62	27·59	7·27	41·70
Sheep, .	8·95	27·21	3·56	40·89
Goat, . .	9·41	31·73	5·90	41·41

The blood is always alkaline, and this was formerly said to be owing to the presenee of alkaline carbonates. Their existence was afterwards denied; instead of being eombined with earbonie aeid, the soda was said to exist as an albuminate, and the carbonie acid to be produeed by the eombustion of matters. The question being again taken up, Liebig and others do admit their existence in the blood. Liebig admits both the carbonate and the biearbonate of soda. He preeipitated albumen from the blood, burned it, and found no alkaline reaction, and from this concluded that the alkali was not eombined with the albumen. Very eapable men defend each side of the question, and it eannot as yet be eonsidered as settled.

The salts of the blood are not, then, uniformly distributed in all parts of the blood. They exist in all, but in different proportions.

METALS.

Iron, manganese, copper, lead, and even arsenic, have been said to exist in the blood. The iron is localized, and has been shown most positively to exist only in the globules. The plasma contains no trace of it; it was formerly said so; but when the clot is left in the serum, there is a solution of the iron before entirely localized in the globules. It is found in combination with another matter,—hematine, the coloring matter of the blood. This iron does not give the hematine its color; but it is only when combined with iron that it has the property of varying in intensity. It is, moreover, from the iron it contains that the hematine possesses the property of absorbing oxygen. The proportion of iron in the hematine is ever the same, namely, six per cent., and it has been said that, by knowing the quantity of iron, the quantity of hematine in the blood could be calculated. Relatively to other matters, the proportion of iron in the globules is considerable. In a hundred parts of dry globules, the iron is in the following proportion in these different animals:—

Man,	0·4348
Ox,	0·5090
Pig,	0·4480
Chicken,	0·3260

These quantities can vary; as, for instance, in chlorosis there is a diminution of the iron, and when

the iron varies the hematine does. The simple administration of iron is not sufficient in the treatment of chlorosis; for should it find no hematine, it does not fix itself. The want of iron can then depend upon a want of hematine. M. Bernard will hereafter return to this question.

Manganese and copper are said to exist normally in the blood. Manganese is said to play a part about like iron, and the same thing has also been asserted of copper. Lead and arsenic are not supposed to be found in a healthy condition, though M. Orfila says that arsenic can normally exist. There is, however, a great difference between these other metals and iron. Iron exists only in the globules, and this has not been shown for the others; moreover iron is never found in the secretions, it is never found anywhere but in the globules and in the hair. The others are eliminated in the secretions, and again they localize themselves in the liver. The iron is found in less quantity in the liver than anywhere else; that is to say, there is less in the blood of the liver than in the blood of other organs. We cannot then admit that these metals play a part in the organism such as iron does. No other metal than iron can be considered as playing a physiological part. Those others also are poisonous; but iron is not, for much of it may be injected into the blood without harm.

All the analyses already given have been general, as others will be given hereafter when the

blood of particular parts, or when *particular bloods* are described.

GASEOUS MATTERS.

The gases in the blood are those found in the atmosphere: oxygen, azote, and carbonic acid; and it is natural that they should be. Their proportions are however very different. In the air we have in volume 20·90 parts of oxygen, 79·10 of azote, and ·0005 of carbonic acid; in the blood we have 78 parts of carbonic acid, 12·5 of oxygen, and 3·3 of nitrogen.

The nature of these gases never changes; but while in the air they always have the same proportion to each other, in the blood their proportion varies very much, for instance, the azote varies from 1 part to 3. The blood is not saturated by the quantity of gas it contains, but can dissolve much more; it can for example dissolve 25 parts of oxygen. A great number of researches have been made to see if all bloods—that is, blood from every part of the body—contain the same quantity of gas. Both venous and arterial are found to contain the same gases, but in different proportions; in the former, the proportion of oxygen to carbonic acid is but 4 to 16, while in the latter it is 6 to 16.

This absorption of gases is said to be effected by the globules. An immense difference in absorbing power is found to exist between pure

serum and blood deprived of its fibrine. Defibrinated blood, or serum with the globules, can absorb 25 parts in 100; and serum alone only one-half or one-third of that amount. When defibrinated blood is taken and oxygen made to pass through, we see at first that carbonic acid is displaced, but after a time that the oxygen comes out unchanged. This carbonic acid existed previously to the passage of the oxygen, and has not been formed, as might be supposed. If the blood be left in repose three or four hours, and the same thing be repeated we find again carbonic acid. This shows that some had been formed, that the oxygen taken in changes and goes to form carbonic acid. It is thus seen that in making experiments upon the blood, you must take it as it is coming out of the body. If arterial blood be left exposed to the air for twenty-four hours, it will be venous, the oxygen it contained having gone to form carbonic acid.

In the globules the substance having this property of the absorption of gases, is particularly the coloring matter, as is shown by a very simple experiment. Take some globules and allow them to remain some time in water, the coloring matter dissolves, the water becomes red, and the oxygen it contained before becomes transformed into carbonic acid.

This property, then, of the absorption of gases chiefly resides in the globules, the serum possessing but very little.

In the putrefaction of blood, the organic and inorganic matters separate. It is thus that the inorganic matters are then found; they are not *formed* at that time, as has been said. The coloring matters lose the property of becoming red. The fibrine produces several acids, among which is lactic; and what is very interesting as regards the transformation of albumen into fibrine, and vice versa, is that fibrine in putrefying dissolves, and the liquid then presents all the characters of albuminous fluids, coagulating by heat and by acids. At the moment of putrefaction a peculiar coloring matter is produced. M. Bernard showed the blood of a duck that he had kept for more than a year. Upon adding water, there was a coagulation, and on filtering, a yellow fluid was obtained, that had the property of becoming a beautiful red under the influence of sulphuric acid. This is interesting, for it is true of the blood of all animals. It is only found, however, in some parts of the body; neither the muscles nor the brain contain any of it, and on the contrary, it is found in great abundance in the liver, the spleen, the kidneys, and the pancreas. At one time, M. Bernard found so much in the last organ that he thought to make it a distinctive character of the pancreas; but continuing his researches, he found it also in the blood of other organs. To obtain it he allows the part to putrefy in water, and then he filters the liquid.

M. Bernard has so far confined himself to gene-

ralities, he now enters into the subject to be considered.

Arterial blood is everywhere the same; from the heart, or from the spleen, it is *one*. Of course, its composition should be for us the type; it should be the primitive blood, so to speak. The blood enters organs essentially different, and it must of necessity be differently affected by them; the same upon its entrance, there is a difference when it issues. Clearly, the blood must be deprived of different materials to make pancreatic juice, sugar, &c.

Arterial blood is that between the lungs and the capillaries, whence it comes and where it enters. Of course, the blood in the pulmonary artery is not comprised. Arteries have been defined as vessels holding red blood, and veins as vessels holding black blood. This, from what has been said before, cannot be correct. Again, arteries have been defined as all vessels in which the blood has a centrifugal direction; this definition is good in a mechanical point of view, but in a physiological point of view we cannot preserve it.

There is between the blood that enters, and the blood that issues from the lungs, an immense difference, a difference that chemistry has not yet shown, a difference of life and death. For us, arterial blood is the vital blood, the blood maintaining life, and this blood is that between the lungs and the capillaries. The pulmonary veins carry it to the left auricle, thence it goes to the

ventricle, and thence to the aorta: the lungs furnish, the heart propels.

The lungs are formed of a sponge-like substance that can be much dilated; it is a capillary system different from the others. Eminently extensible, on the surface are vessels of the greatest tenuity, and in the interior is air.* At the moment when the lung is filled with air, there is an emptying of blood into the veins, and the venous blood precipitates itself into the lungs. When the veins are engorged, make a deep inspiration, and this effect will be observed. The venous blood entering the lungs, chases the other; at the moment of its entrance, the lungs empty themselves of what they previously contained. When this action of the lungs, respiration, is arrested, the circulation is more or less arrested. More or less blood enters the lungs, as the respiration, is deeper or smaller, and more or less is sent to the heart. There are persons who can retain the respiration long enough to let the arteries empty themselves. Muller says he can do so himself until he has no radial pulse. To see if a hemorrhage be arterial or venous, hold the breath, and if arterial it will diminish, while, on the other hand, rapid breathing will cause it to increase. There is incessantly a reaction of the respiration upon the arterial circulation as well as upon the venous.

The blood circulates under the influence of two principal causes, pressure and impulse; the former

* See Appendix, Note C.

from the arteries, the latter from the successive contractions of the heart. When the dilatation of the lungs has *pushed* the blood to the left heart, this sends it into the arteries, which are composed of a yellow tissue, having the elastic property it possesses everywhere in the body. This elasticity is purely and simply mechanical, existing as well after death as before, and not acted upon by galvanism or anything else. The heart distends these vessels by forcing blood into them, and then they tend to contract upon themselves. The mechanism has been compared to that of a fire-pump, in which the constant action is from the elasticity of the air. Magendie's experiment to show this action of the arteries was this: he isolated an artery, applied to it two ligatures at a certain distance from each other, and then made an opening into the vessel between them. There was a jet of blood, and the walls came into contact with each other.

Instruments have been constructed in order to measure the force of these two causes. One used in the last century was simply a tube of copper, in which, when applied to the carotid of a horse, the blood was found to ascend six or eight feet. With this instrument, however, these forces cannot be properly studied. M. Poisseuille made use of an instrument, that is neither more nor less than a barometer, being a curved glass tube, in which the mercury is in equilibrium. He used it chiefly in order to measure the force of what he

called the aortic heart. M. Ludwig has imagined an instrument that permits very satisfactory results to be obtained. There is a barometer, as in the other, but in one end a wire is inserted, to move with the variations in the height of the mercury. Attached to the upper extremity of this wire is a pencil, which is in contact with a sheet of paper fastened to a revolving cylinder. The pencil marked great oscillations, composed of three or four smaller ones. The great oscillations correspond to the respirations, the smaller to the pulsations of the heart.

All observers, though making use of very different instruments, have arrived at very analogous results. M. Poisseuille said the pressure was the same over the whole arterial system, and it is correct that under the same conditions it is invariable; in every point of the system you have the same cipher, whether it be the aorta or the arteria dorsalis pedis.* It is about the same in all animals, the difference not being sensible in the dog, the rabbit, and the horse. In the rabbit, when fasting, it was 95 millimetres, in the dog 103, in the horse 110. The difference is not great, as is seen, and the pressure in the same animal, when he is under different conditions, varies much more than that. The impulse of the heart, however, which it is very important to distinguish from the other force, varies in different animals. The oscillation at

* As will be seen, M. Bernard shows this to be a mistake.

each impulse in the rabbit was 5 millimetres, in the dog 12, and in the horse 40. The causes of the movement, then, of arterial blood, are pressure, impulse, and respiration, coming from the arteries, the heart, and the lungs. One cause is continuous, the others are intermittent. The phenomena, witnessed at the opening of an artery, can thus be explained. At first the jet is continual, not interrupted, owing to the pressure of the full arteries; after a time it becomes jerking, for the arteries are no longer distended, and at each inspiration it diminishes, and at the expiration increases. These phenomena are seen very well in animals slaughtered by the Jews, who cut directly down upon the vertebral column.

In the different measures taken of the force of the blood in the arteries, all these three causes have generally been confounded. They should be distinguished, for they are not all subject to the same influences.

In making these experiments, M. Bernard used the barometer, previously introducing some carbonate of soda to prevent the coagulation of the blood. A fixed point showed the pressure of the vessels; the oscillations were produced by the action of the heart. When the animal was quiet, the effect of the respiration was not very evident; but when agitated, the mercury mounted higher than the scale. The pressure in this animal was 120 millimetres.

The pressure of the arteries diminishes when

the animal is fasting, as is easily understood, for it augments and diminishes with the quantity of blood. To show the considerable difference resulting from the quantity of blood, in one experiment of M. Bernard, while before bloodletting the pressure was 141 millimetres, it was but 57 afterwards. M. Magendie applied a syringe to a vein, and as he drew out the blood, he saw the mercury descend, and ascend as he pushed it in. Again, by tying the arteries, you cut off some blood, and there is an augmented pressure in what is left, as M. Bernard showed by applying a ligature to one carotid of a dog, when the instrument was attached to the other. During digestion a great quantity of blood is added to that already circulating. Every cause, then, that affects the quantity of blood affects the pressure.

Whenever the respiration is free, the pressure diminishes. In expiration, there is constantly an augmentation of pressure, which a cough or a sneeze produces very suddenly, so that it is not rare at such moments to see the bursting of an aneurism.

The influence of the nerves upon the arterial pressure is very marked. That of the par vagum is very great. When this nerve is divided, whenever the lower end is galvanized, the pressure is diminished; when the superior end, the effect is quite the contrary.

M. Magendie has experimented on other nerves. He found upon touching the root of a

spinal nerve that the heart stopped for a few seconds, and that afterwards the mercury in connection with the circulation, rose or fell, as he touched the posterior or the anterior root. When the animal is feeble, this stoppage of the heart may be fatal; even a pinch may destroy life. This action of the nerves on the heart must always be taken into account.

M. Bernard injected different substances into the circulation. When blood was thrown in, an exaggerated plenitude, and consequent greater pressure, were produced. This was not the effect of the introduction of water. He found other substances to act otherwise than by mere quantity, as, for instance, coffee augmented very much the pressure, and, as has just been said, the effect could not be attributed to the quantity of water with which the decoction had been made.

This pressure is alike in all organs, yet we are not well acquainted with its influence upon them. In the organs of secretion, M. Ludwig has recently studied its effect upon the salivary glands, and these are found to undergo no change from pressure. The phenomena must be studied successively in all the organs. In the kidneys it is seen that purely mechanical as well as vital conditions react. A dog having a pressure of 76 millimetres, gave 0·80 grammes of urine in a minute. The arteries of all his limbs being tied, the pressure was 112, and he then gave 12·23 grammes. The secre-

tion of urine then augments with the pressure. In another case, the animal was bled: the pressure was 57, and in one minute he passed 2·06 grammes. After an injection of blood, the pressure was 122, and 19·34 grammes of urine passed. In another, when the pressure was 134, 9·55 grammes were passed; after bleeding until it was but 119, only 4·92 came away. The same was the result when the action of the pneumogastric nerve upon the pressure was called into play. In an animal where the pressure was 135, and in one minute the urine 10·66 grammes, upon galvanizing the lower end of the divided nerve, the pressure was but 105, and the urine 4·36. The influence of the arterial pressure then, upon the renal function, is very manifest, the one augmenting and diminishing with the other. We must not, however, attribute all the phenomena of the economy to this same cause. In diabetes, for instance, the great quantity of urine passed can be accounted for by the great quantity of drink, causing unusual arterial pressure; but in some nervous affections, where there is no increase of pressure, there is an exaggerated amount.

There is a theory that all secretions are but filtrations, depending upon the force of the blood and the resistance of tissue, the blood being contained in a vessel, and a wall being between it and the cavity of the cell into which the secretion is poured. This theory has been developed and

maintained by Henle. If this be true, we must admit that the products are previously existing in the blood, that when there is an equilibrium between the force of the blood and the resistance of the tissue, there is no secretion, and when there is a defect in the equilibrium, when the pressure is greater in the bloodvessel, there will be a flow into the cell. These experiments upon the urinary organs are very favorable to this theory of filtering; but we must never generalize, and taking the salivary gland, we will there find that there is not the slightest relation between its secretion and the arterial pressure. M. Ludwig, of Zurich, made this experiment:—taking a salivary duct, he applied a barometer so that the saliva secreted would make pressure on the mercury, and measure this pressure in millimetres. The column of mercury raised up was 215 millimetres, while the arterial pressure was but 140, as has been before stated. This fact also shows conclusively that there is a complete want of accord between the two. This is never known in the kidneys, where the pressure of the blood is always the greater. By exciting a branch of the lingual nerve, the pressure of the secretion can be augmented, so as to measure 400 millimetres. While, then, the pressure of the blood continues the same, the secretion of the saliva changes very much, and again the secretion may remain undisturbed when the arterial pressure has varied. If you suddenly decapitate a dog, and excite the lingual nerve, you will have the secretion

of saliva, though here the arterial pressure cannot exist.

If these two secretions, the salivary and the urinary, be reflected upon, it will be seen that they could not act under similar influences, that they could not be regulated in the same way. The secretion of urine is constant, and must be under the influence of pressure, for it is connected with the purification of the blood. The salivary secretion is connected with certain acts of the digestion. The excretions must be distinguished from the secretions, which are not thrown out, whose active principles do not previously exist in the blood, but are formed in the organs, and are connected with certain acts of the economy. All such organs having these active principles in themselves, are not influenced by the external pressure, while those acting the part of a filter always are.

The liver is probably between the two, between secretory and excretory. Suppose an obstacle, a calculus, for instance, to oppose itself to the excretion of the urine, the arterial pressure being resisted, the kidney will no longer secrete; the products usually excreted accumulate in the blood, and the accidents resulting from their non-elimination take place. When there is an obstacle to the elimination of the bile, those principles that certainly previously existed in the blood, are then retained, and the individual is jaundiced. But nothing similar can ever take place in the salivary glands; they become swollen, the products

remain there, and never are found in the blood. Independently of these organs, there are many others that perform their functions differently as the pressure varies. As a general rule, the functions, cerebral, muscular, &c., diminish with the pressure. The action of coffee has thus been explained by some physiologists.

There are in the nervous system, particularly in the brain, two movements, one of the arteries, and another of the veins, dependent upon the respiration. This is seen by trepanning an animal, and has been much studied by M. Magendie. The compression exerted by the veins, is diminished by inspiration, and every time the pressure is diminished in the veins, it is in the arteries. This is seen also by obstructing and by opening the jugular vein.

The impression of the heart's action upon the circulation determines the pulse. This force must be distinguished from the arterial pressure, and unlike it, is not the same in all parts of the body. While, again, the one is about the same in all animals, the force of the heart's impulse is different in different animals; in the rabbit, it is 2 or 3 millimetres (that is to say, it will raise a column of mercury that high); in the dog, it is 13 or 15; in the horse, 30 or 40.

As a general rule, the impulses are weaker in proportion as they are more frequent, and stronger as they are less so; in the horse, where the column was raised 30 or 40 millimetres, there are but

40 or 50 in a minute. The same thing is very often true, in regard to the individual, the more frequent, the more feeble; but still it cannot be applied as a general rule. When the shock of the heart takes place, the tube of the artery changes in diameter. Physiologists generally argue as if the tubes, after the heart's contraction, were full, but they are far from being so. They speak moreover as if the sigmoid valves were forced widely open, and applied against the walls of the artery, and they have gone so far as to say that the use of the corpuscles of Arantius is to prevent their too perfect application against the aortic walls, so that the blood can get behind and force them back. But it must be remembered that there is a constant pressure in the aorta sufficient to raise a column of mercury 140 millimetres. At the moment of the heart's contraction the aortic tube augments in diameter, and the sigmoid valves simply half open themselves; they never can do so widely, for that is prevented by the great pressure from above.

M. Bernard has not been able to apply a barometer to the left ventricle, but he has succeeded in the right. In the pulmonary artery the pressure is only 40 millimetres, far less than in the aorta, yet we can reason after the relation these parts bear to each other. In the right ventricle he took the pressure by introducing a tube through the pulmonary artery into the interior of the heart. At each contraction of the heart, the mercury was raised 60 millimetres, and then it descended to

zero, for there were no valves to the barometer; and this shows that there is no constant pressure in the heart.

The pulse, then, is caused by an excess of force over the arterial pressure, exerted by the heart at each contraction.

The dilatation in the arteries by the pulse has been measured. M. Poisseuille surrounded the carotid by a tin tube of much greater diameter, and closing the ends he filled the intervening space with water. With this space a barometer communicated, into which the water mounted at each impulse of the heart. He thus calculated the dilatation of the artery at each pulsation to be the $\frac{1}{23}$ of its diameter. Another plan was to surround an artery with an elastic ring having a spring attached to it. This demonstrated the fact, but you cannot thus measure the dilatation.

What is the rapidity of the circulation? The observations that have been made are generally for the entire system. At first they desired to find the time in which all the blood would circulate, by calculating after the quantity, the capacity of the heart, and the number of beats in a given time. At the present day there are several methods. One is that of Hering, of introducing in one vein, and watching for in another, some chemical substance, as the prussiate of potash, innocent in its nature, and easily recognized. Hering experimented upon horses, probably on account of his situation, in a veterinary school, in Stuttgard. He made an incision into

the jugular vein, and introduced the salt, not by a syringe, for then it must be pushed, but by means of a funnel, the same they use for economy in the administration of medicines.* The exact moment at which it enters is marked, and at the same instant the other jugular is opened, and its blood tested every five seconds. At the end of the fifth trial, that is, at the end of twenty-five or thirty seconds, they can detect the salt. In that time it has already traversed the small circulation, and the whole of the great. There are of course some seconds of difference when parts at a greater distance from the heart are taken, as the legs, for instance. This rapidity is not sensibly modified by the number of pulsations; when forty or eighty, there was no perceptible difference, nor was it found to be influenced by the respiration. These are the observations of M. Hering.

This rapidity can be far greater in other animals; in a dog, scarcely ten or twelve seconds are necessary, and upon the rabbit and animals of that size it is impossible to make the experiment.

Poisonous substances have been used, in order to see how soon their effect would be produced; for, to produce an effect they must be spread through the system. Half a grain of nitrate of strychnia acted $4\frac{1}{2}$ seconds after its injection into the jugular vein of a rabbit; in a horse, six grains,

* This plan is used in veterinary practice in some parts of Europe, as a much smaller dose will answer, than that requisite in any other.

at the expiration of sixteen seconds, and in a goose, one grain at the end of $6\frac{1}{2}$ seconds.

These means of measurement have not, however, the exactitude that could be supposed, for there is nothing to prove that all substances circulate with the same rapidity. Some substances are *diffused* with greater rapidity than they *circulate.* Iodide of potassium, is much quicker than the prussiate of potash, and, on the contrary, cane-sugar is much slower. These same objections have already been made by Matteucci.*

Lamp-black has been taken, but it forms itself into flakes, that stop up the capillaries. Seeking, again, something that would remain in suspension, the blood-globules of birds have been used, but they do not answer, as may be known from what has before been said of them—that they disappear and cannot again be found.

Volkmann proceeded as follows, his object being principally to find the rapidity of the blood in the arteries. He used a tube, connecting the extremities of a divided artery, and in which was a kind of curved handle, into which the blood can be made to go, by turning the stopcocks. Carbonate of soda having been introduced, the rapidity with which it was pushed up, after the turning of the stopcocks, was measured by a watch marking seconds. In the carotid of a horse, the

* The American edition of "Matteucci's Lectures on Living Beings," page 319.

movement in one second was 546 millimetres, in a dog 273, and in a goat 318. The capacity of the arterial system becoming greater and greater as you recede from the heart, the rapidity of the circulation ought then to diminish as you approach the capillary system. Volkmann's experiment gives eighteen seconds for the whole circulation. There is this, also, that the rapidity is greater in the horse, than in the others, which is at variance with the results of other experimenters. What we can determine from all this is, that the rapidity of the circulation is very great.

The possession of the property of contractibility by the arteries has been much discussed, but is now decided. In the large trunks there is scarcely any. Their elasticity is all, but as we approach the capillaries, this diminishes, and the contractibility increases. Both properties exist everywhere, but as we have stated. If the artery of a large animal, just dead, be measured, and the measurement be repeated at the end of two or three hours, it will be found to have increased in diameter. It has then really a vital contractility, but it is so very slight, that if galvanism be applied, no effect can be observed. When you come to the capillaries, you find contractility. There are many parts contracting perfectly well where no striated fibres, no muscular fibres, properly speaking, are to be found. The capillaries contract under influences not affecting the muscles: cold makes them contract, and heat has the contrary effect.

This is well seen in the bladder of a young rat, that lives perfectly well while it can be examined under the microscope. In the large arteries the elastic tissue is found, which is very rare in the small, while in them the contractile tissue is found predominant. The contractile membrane of the arteries is formed of flat muscular fibres, that dissolve perfectly in acetic acid, thus being distinguished from the elastic and muscular tissues, and situated just outside of their lining membrane.*

It is the sympathetic nervous system that acts especially on the dilatation and contraction of the vessels. M. Bernard divided the great sympathetic corresponding to the part of an animal, in order to show the profound change that takes place in the whole circulation of the region. In a rabbit, whose ears were transparent, and of equal temperature, he divided the nervous branch connecting the upper with the lower cervical ganglion. The experiment is quite a delicate one, for it is necessary to avoid any effusion of blood. The same effect would be produced by removing the upper ganglion. The change was visible, not only in the ear, but all over the same side of the face, the ear being particularly mentioned, because in that part, from its transparency, it is more easily seen. There was an augmentation of the vascularity, of the sensibility, and of the heat, with no alteration in the movements. The arterial system at the

* See Appendix, Note B.

peripheric extremity is under the influence of the nerves, and the great sympathetic is the special nervous system of the circulation.

In the phenomena above mentioned, some have only been willing to see a paralysis, and have maintained that the section of any motor nerve would be followed by the same. But it is absolutely only the sympathetic. It is true that you can by the section of the facial nerve, produce a *little* greater activity of the circulation, but in the course of its passage, this nerve anastomoses with the great and small petrous nerves, which are in truth only branches of the sympathetic. Cut the nerve in the cranium before its union with these branches, before any anastomoses with the others, and no effect whatever will be produced on the circulation. When you take the roots of the spinal nerves, and cut all the anterior and posterior branches, you have just an opposite effect, the temperature always diminishing. If you cut all the nerves supplying a part, the sympathetic as well as the others, there may be no change. When the *cephalo-rachidian* trunks are alone divided, there is always diminution in the temperature, and when the *sympathetic* alone, it is always increased.

M. Magendie said at once that the increase of heat was owing to the greater circulation, but there are circumstances that render this explanation a difficult one. When the veins of the part were tied, and the blood thus forced to stagnate, the heat was still found to continue greater.

Moreover, there are cases in which the calibre of the vessels is increased, and yet the parts are cooler; as when you cut the fifth pair of nerves in the brain, there is likewise a stasis of the blood. Again, it has been wished to explain these phenomena by a paralysis of the arteries, and their consequent dilatation, and this is said to be shown by the contraction of the vessels, and the expulsion of the blood by means of galvanism. But still this does not explain the increase of heat, for the blood can be accumulated in a part by means of a ligature, and while the parts become engorged, they become cool. M. Bernard will show hereafter that the mechanism of these phenomena is active, and not passive, that the blood is warmer when it leaves the part than when it entered, and that the effect is upon the capillaries, the large vessels being simply elastic tubes, and but indirectly affected by the experiment.*

The transportation of the different substances introduced into the organism is a very important question. It is impossible to admit of any other intermediary between an organ and the acting body, than the bloodvessels. M. Bernard, in proof of this assertion, cited the well-known and most conclusive experiment of Magendie. When a leg was only connected to the rest of the body by means of the sciatic nerve, no effect was produced by the introduction of prussic acid into the limb.

* See Appendix, Note E.

When the artery and vein were alone left to form the attachment, when the artery was pressed upon the poisoning took place perfectly well, but when the vein was pressed upon, it was arrested. The substance is placed in the circulation by the veins, and the arteries afterwards carry it to the organs. This necessity which substances are under, of passing by the arteries, renders it necessary that they should pass through the heart. Touch a nerve with strychnine, place prussic acid on the brain itself, and no effect is produced, unless they pass, by the veins, into the circulation. Almost all poisons, as will hereafter be shown, act upon the nervous system, after being brought into contact with it by the arterial.

Gases will first be spoken of, for more experiments have been made with them. It is perfectly well known that the oxide of carbon is very poisonous; when respired, death occurs promptly, and with peculiar symptoms, and yet when introduced into the veins it has no effect. Liquids introduced into the veins act very promptly.

Three hundred cubic centimetres of carbonic oxide were injected into the veins of an animal in twenty minutes, and no injury resulted, while the fourth of that quantity when inhaled is instantly fatal. This must be explained by its never having reached the arterial system, and this fact requires demonstration. When a gas is injected into a vein, it is carried to the right auricle, from thence to the ventricle, and then to the lungs. If

the gas has been suddenly injected and the blood has not had time to dissolve it, the capillaries of the lungs may be obstructed by the bubbles, and a *mechanical death* may result, just as when pure air has been rapidly introduced. The carbonic oxide is much more soluble in the blood than in water, as are all gases, and when injected with sufficient slowness, is dissolved, and upon its arrival in the lungs, which are charged with the expulsion of gases from the body, it is thrown off. In simple words, the carbonic oxide *goes away*. The same thing occurs when air is slowly injected; the whole, the nitrogen and all, is dissolved, and goes away in the lungs. If in place however of the jugular vein, you inject but two or three cubic centimetres into the carotid artery, the animal will be instantly destroyed. It does not act by going to the brain, and there obstructing its capillaries, for it is perfectly dissolved, so that none can be found anywhere.

The same thing is true of carbonic acid, of which enormous quantities can be injected, for it is exceedingly soluble. That this gas, when thrown into the veins, never arrives in the arteries, but goes off in the lungs, is proved by what is produced in the animal, for no bad effects ever follow. When introduced directly into the lungs, it is absorbed by the radicles of the pulmonary veins, and carried to the heart, whence it goes to all the organs, and destroys life. The same thing is true also of its effect when thrown into the arte-

ries. If but five or six cubic centimetres are injected into the carotid, death ensues, in about an hour, with the symptoms of apoplexy, and it is impossible to recall the animal to life. Enormous quantities of this carbonic acid can be absorbed by the skin, and no bad effects happen. The same is true of gases in the intestines, for after their absorption, they must traverse the lungs, whence they are thrown off, before reaching the arteries.

M. Bernard injected a very large quantity of carbonic acid under the skin of a rabbit, and no effect followed, for it is the radicles of the veins that absorb. Such an experiment, then, as far as gases are concerned, is not at all conclusive as to whether or not they are poisonous. When a liquid is injected, it is not at all the same thing, for the substance traverses the lungs, and enters the arteries. It will hereafter be shown that sometimes the kidneys can act with liquids as the lungs do with gases, can throw them out and prevent their reaching the arteries.

If then a poisonous gas does not act, it is because it is eliminated in the lungs, and this can be shown by finding it in the expired air. A hole being made into the trachea, a tube having a bladder attached is introduced. When no gas is introduced into the veins, you find there oxygen, nitrogen, and carbonic acid, but if you inject carbonic oxide, you will find it also in the bladder. This is direct proof of its not being transported to

the arteries. Another cause of error in these experiments is the following. Nysten injected gases into the jugular vein, and at the same moment he opened the carotid to see the color of the blood. He injected oxygen, and believed he could thus keep the blood red, and moreover he supposed he could by such an injection avoid the necessity of respiration. It was not so, however, for the oxygen passing off by the lungs, the animal died. The blood of the artery instead of being kept red, became black, for the oxygen caused a greater or less mechanical obstacle in the lungs. Nysten found all the gases, when injected into the veins, to blacken the blood of the arteries.

Almost all poisonous substances act upon the nerves, some of them upon the muscles, and to get there, they are forced to go by the arteries. When introduced into the veins, if capable of going off by the lungs, they do not act. They can, however, have a special action on the lungs, yet never can they act as toxical.

What is true of gases is likewise true of volatile bodies. All liquid substances introduced into the veins, enter the arteries, if they are not previously forced to pass through the kidneys, for then they may be eliminated.

ARTERIAL BLOOD.

The blood in the arterial system is separated from the venous by the lungs and the capillaries,

so that it remains unaltered. It has long been said to have the same character, in the left ventricle, that it has in the extremities. The differences are so slight, that they are very difficult to determine, and moreover researches have generally been made upon the venous blood. Legallois, who made many experiments, said it was everywhere the same, for he maintained it cannot change, it cannot mix with any other; though there can be passages between an artery and a vein, there never can be any from a vein into an artery. Press an artery, he said, and you see that the vessel below the point is emptied; press the vein, and you never will find any blood in the artery, though all the parts become engorged. Again, said he, they cannot absorb. Magendie, however, has shown that they do absorb; that they do so by imbibition, though the action is much slighter here, where the walls are very thick, than in the veins, where they are much thinner. Take the artery of a young dog, and hold around it a poisonous principle, at the end of a certain time, some twelve or fifteen minutes, it will take effect. In a general way, they may be said not to absorb, but it is not an absolute truth.

In man, then, arterial blood is to be considered identical in all parts of the body. In all animals where there is a mixture of the arterial and the venous blood, there is less activity of the vital actions, and the same thing is seen in man, when

it happens locally, as after a wound establishing a communication between the vessels.

The arterial blood has the same temperature from the heart to the extremities, being at 38° or 40° Centigrade. It is *about* the same; it can be somewhat less than that, but the difference is never more than one degree. In the veins it is not so, there is a great variety in the temperatures.

It contains more oxygen, less carbonic acid, less water, and a smaller quantity of sugar and of some other substances than the venous.

The diminution of water is explained by the pulmonary expiration, for there is a very considerable exhalation of it in the lungs. Magendie has shown that the quantity exhaled could be increased or diminished at will; by the injection of water into the circulation, it is increased.

As to the diminution of carbonic acid, and the increase of oxygen, they are very naturally explained by the changes in the lungs. This oxygen must not be regarded as existing in the condition of oxygen. It is important to know that in making analyses of the blood, it must not be allowed to remain long after its withdrawal from the body, for all the oxygen is transformed by degrees into carbonic acid. The characters of the blood are exceedingly fugitive, and to find them, it must be tested immediately upon its extraction. As a demonstration of this, M. Bernard showed the blood of an artery and that of a vein, drawn

the day before, and it was at that time almost impossible to distinguish them, both being nearly equally dark. A theory to explain the coloration of the blood has been founded upon this, which maintains that the blood is primitively black and is changed red by oxygen, and that when the oxygen changes its state to become carbonic acid, the original blackness returns.

That there is less sugar is easily understood, for, carried to the heart from the liver, it is sent to the lungs, and among the changes occurring there, is a great alteration in the quantity of sugar. If there be but little, the whole is changed, and not a trace is found in the arteries; it can only be detected in them, when the experiment is made during digestion, at which time a greater quantity is present in the circulation. Its existence in the arterial blood must therefore be considered exceptional.

More fibrine is stated as the result of analysis, by many authors, to exist in the arterial blood. It is not, however, so easy to extract the fibrine from the blood as may be supposed, and different methods give different proportions. When the blood is allowed to coagulate, you always obtain more than when you extract it at once. M. Bernard promised to make some researches on the subject, and to give the results before the close of his course, but he never again referred to it.

The blood-globules are said to be smaller in the

arteries, but it is difficult to decide if this be true, for they are all so very small, and they are, moreover, of various diameters.

Many substances undergo transformation in the organism. Sugar, for instance, disappears at the moment of the formation of the arterial blood. Magendie introduced starch into the circulation, and it was observed to change into sugar, and to disappear, and these changes were observed to take place more easily in arterial blood than in the venous, probably on account of the oxygen it contains.

Do these changes take place by chemical action, or what is the cause of them? It is easy now to answer, for there can no longer be a doubt, that they all take place by *fermentation*. Arterial blood absorbs oxygen and abandons it, and this absorption varies and disappears, under the same circumstances as many fermentations, as, for instance, upon the lowering of the temperature. In making beer this is seen, and again we see that it ceases when the heat is raised above 75° Centigrade, by the destruction of the organic principle producing the phenomenon. So in the blood, oxygen is absorbed in smaller quantities in the cold, and the effect is the same whether the blood be cooled artificially in a vase, or in the body. By raising the temperature the oxygen is found to be absorbed in proportion as the temperature rises. At 45° Centigrade, however, this principle in the blood, that absorbs oxygen is destroyed. Magen-

die has made many experiments on keeping animals in high or low temperatures; after long resisting the influence of heat, they finished at the end of a certain time by becoming warmer, but they never became hotter than 45°, when they died. It is precisely at this temperature that the blood ceases to absorb oxygen. This property is also lost when the temperature is very low. In the one case the blood is everywhere very red, both in the veins and the arteries; in the other, after the elevated temperature, on the contrary, it is everywhere black.

There are then in the blood organic matters whose existence there is necessary for the absorption of oxygen. The phenomena which take place under their influence are the same as those of fermentation. All the liquids that act in digestion, act in this way; the gastric juice acts in virtue of an organic principle, and the pancreatic juice also. Pepsin has been found: it is purely and simply a ferment; experimenting with it, digestion will be found to commence at 10°, to increase to 40°, and then to diminish to 60°, when it ceases altogether. Without knowing this, Spallanzani made experiments on snakes, leaving them in the cold, and he found them to remain fifteen days without digesting. It is the same thing with the pancreatic juice, which ceases to act when the heat is so great as to coagulate it. This ferment acts in an alkaline medium, pepsin requires an acid one; that of the blood must be alkaline. Neutralize

the gastric juice, and it no longer digests; it may be said that this is because it is the acid that digests, but take it alone and it does not. It is the *ferment* that digests, it must not be supposed to be the acid. The blood to absorb oxygen must be alkaline; it is normally so, but it is not the alkali that gives it this property, for a temperature of 45° does not destroy the alkalinity; it ceases then, because at that point the organic principle is destroyed. This special ferment has not as yet been isolated in the blood, but if none existed there, temperature would not exert the influence it does, upon its properties.

Arterial blood never presents a buffy coat, as the venous is well known to do. This is easily observed in animals after death, when the white clot found in the right ventricle is never seen in the left. This might put us in the way of finding a reason for this buffy coat; it would appear as if, in traversing the lungs, a more intimate connection took place between the lymph and the blood.

As a basis, as the type of all blood, M. Bernard will then take the arterial as the most perfect of all, since it is necessary to the vitality of the organs.

The blood in the different parts of the body varies according to the metamorphoses it is made to undergo in the different organs. That of any part might be chosen to commence with, but M. Bernard prefers that in the portal vein. The choice is entirely arbitrary, yet as many new substances from without enter the intestinal veins,

he preferred commencing the subject by the examination of the modifications undergone by the blood in traversing the intestines. The vena portarum receives the blood coming from the whole intestine, from the stomach down; as to the mouth and the œsophagus, they are left out of consideration, being only places of *passage*, and only those parts will be taken where the blood is really altered, where the intestine is really active. The vena portarum receives also blood from the spleen, the pancreas, and the mesenteric glands, and their blood must be distinguished in studying the portal blood. What is said, moreover, is only true of the mammiferous animals; in birds, fish, &c., the portal vein is otherwise disposed, in accordance with certain physiological functions. In the mammiferous animals the portal system is *closed;* when you take blood from there, you are sure that there is none from the lower extremities, by communication with the crural vein, and that the blood can only leave the intestines by that route. In the other animals, large communications exist with other veins. The blood will therefore be now taken from a mammiferous animal, and the variety of function, arising from difference in structure, will be studied hereafter.

Still, however, it must not be believed to be an easy thing to obtain the pure blood of the vena portarum. Although it seems so easy to open a vein and collect it, until M. Bernard had explained the peculiarity in that circulation, not one analysis

was published in which portal blood alone was had. In the analysis of Simon, there is evidently blood from the liver, and it will always contain some when the vein is opened near that organ.

The reason of this is, that the circulation of the vena portarum is one entirely peculiar; it is only directed towards the liver on the one condition that there is a force to push it there, and this force comes from the abdominal walls, which, by pressing the mass of intestines, propel the blood contained therein. When the abdominal walls are largely opened, the current ceases, and even runs in the contrary direction; for the veins being opened, there is a reflux of their contents. Hence when you would obtain this blood unmixed with another, you must not interfere with this circulation. For this there are two methods. In one, an opening only large enough to introduce the finger is made into the abdomen, by which the vena portarum is felt, hooked up, and tied. This is done while the animal is still living, and by means of an opening exceedingly small, so that not a single organ can come out. The abdominal walls can now be largely opened, for the ligature around the vein prevents any reflux of blood. The blood thus collected differs from that of any other analysis, and is essentially different from that of the liver. The second method is, to seize an intestine so as to have a division of the portal vein, which is opened and its blood collected.

The blood of the vena portarum happens to be

subject to circumstances that must have a great influence upon it; it contains the matters taken up by the act of digestion. In some organs, as the kidneys, no additional principle is taken in from without; but in others many are taken, and the blood is much augmented and altered. This, of course, only occurs during digestion; when the animal is fasting, the blood is certainly modified by passing through the walls of the intestine, but no new matters are added. The circulation here is much more active in digestion than in fasting.

It follows from this, it might be said, that you could tell, *à priori*, what these augmentations and variations would be; for the portal blood being known, when fasting, you should know the changes brought by the elements introduced in the food. This, however, is not exact; for nothing is so variable as the absorption in the intestines—some substances perfectly soluble not being taken up under certain conditions. A first fact is, that all soluble substances do not enter the vena portarum; and a second, that they are not found there in proportion to the quantity taken into the intestines. Some substances, instead of entering the portal veins, go into the lactiferous vessels. M. Bernard has long studied this subject, and Magendie also has remarked the errors in the doctrines regarding the absorption of substances by the portal system. All alimentary substances are either saccharine, albuminous, or oleaginous. Of these the vena portarum absorbs but the first two,

the chyliferous vessels take the last, and fatty matters must therefore be excluded from the list of those found in the portal blood. Oleaginous substances require another system, because they cannot traverse the liver; they must enter the general circulation without meeting that organ on their way. Magendie found, by injecting oil into the vessels going to the liver, that it remained there. In mammiferous animals the thoracic duct empties the fatty matters into the subclavian vein, and they pass through the heart, the lungs, &c., before reaching the liver.

This fact is true of the liver of all mammiferous animals; in the others, a special system of chyliferous vessels does not exist. This system has been said to exist in birds, reptiles, &c., but it is incorrect; the error lies in the observers, and not in nature. There are lymphatics in the others, but they only carry lymph; in the mammiferous alone can they carry fatty matters. In these other animals, the fatty matters go to the vena portarum; but there are in them large communications between that system and the general, and the fatty matters pass directly into the latter.

Only the saccharine and the albuminous matters must therefore be looked for in the vena portarum; and these are not found in proportion to the quantities taken into the intestines, but in proportion to the quantities there absorbed. When the animal has been fasting some time, the absorption is very great; if you then give sugar, in a few mo-

ments you will find it in the vena portarum, and you will even find it in the state of cane sugar. The same thing is also true in regard to albumen.

There is such a thing as a *saturation of absorption.* Give to an animal fasting some sugar, and he will absorb it in enormous quantities, but at the end of a few hours he will absorb no more; though a plenty be found in the intestines, none will be found in the vena portarum. This saturation is true not only in the case of sugar, but also of other substances. This fact shows the incorrectness of the method, given in late works on physiology, for finding the quantity of a substance that may be absorbed in a given time. A certain quantity of sugar is put into a portion of the intestine, and two ligatures applied, above and below; the length of time it remains is then noted, and from that they calculate what would be absorbed in twenty-four hours. This method is correct for the time the quantity has remained there, but it is not correct for the quantity that would be taken up in a longer time.

When there is a saturation of absorption of one substance, if another be given, it will be absorbed. If an animal be always fed upon the same thing, he will become excessively thin and die; a variety of diet is absolutely necessary. By means of this saturation of absorption, there is always a kind of equilibrium between the saccharine and the albuminous matters absorbed. We cannot then in all cases judge by the matters in the intestines, of

what is absorbed. Some albuminous matters, the active digestive principles, pepsin, pancreatin, the active matters of the bile, are never absorbed; they are perfectly soluble, but they are never taken up by the venous radicles of the portal system. The same is true of the venoms secreted in the mouths of serpents. These venoms are *born* in the glands secreting them, and are never found in the arterial blood.

M. Bernard performed the following experiments to prove that these substances are not absorbed. He gave some curara to a rabbit to eat, and under the skin of another he placed a much smaller quantity; the latter died very soon, with no cry of pain, as in all other cases, while the former was not at all affected. He also introduced some of the same poison into the stomach of a dog, through a fistulous opening, without any injury to the animal; but another animal died very soon upon being pricked with an instrument dipped into the gastric juice. That the venom is not absorbed is shown, moreover, by its being found again in the excrements. Again, the Indians, who prepare this poison, use it to inoculate their arrows, and eat the game thus destroyed. After the introduction of this poison under the skin, the more vigorous the animal, the more rapid his death, and animals, as birds, whose vitality is very great, die sooner than reptiles, &c.

There is one fact that could be considered an exception to what has been said above, that of the

three classes of alimentary substances, two were absorbed by the vena portarum, and the third, the oleaginous, by the chyliferous vessels, namely, that sometimes grape sugar is found in the thoracic duct. This, however, is not in opposition to the truth of the statement, and is perfectly explained in this way. If you take the vessels where their contents are sure to be from the intestines, you never find sugar in the lymphatics; but if you take the lymph from the thoracic duct, after the lymphatics of the liver have emptied themselves, you find sugar. These lymphatics of the liver are very numerous; they empty themselves into the thoracic duct at its lowest part, and sugar is constantly found in them. Again, whatever may be given to the animal to eat, you always find sugar in the thoracic duct; it could not come, then, from the substances eaten, but must come from the liver.

The saline matters are very variably absorbed. Experiments have been chiefly made with the prussiate of potash, from the ease with which it can be recognized, and it would seem from them as if the vessels had no election, for it is found in both orders, the portal and the lymphatic. Nitrate of potash has also been experimented upon with the same result.

Again, as a last peculiarity to be noticed, the vena portarum communicates very readily with the lymphatic system; the number of the communications is much more considerable than in the other veins. In some animals, in place of

mesenteric glands, there are venous plexuses. All observers have noticed that the chyle below the mesenteric glands coagulates quite imperfectly, and does not become rosy on exposure to the air; while beyond them it coagulates better, and is much more rosy. It would seem, then, that some principles of the blood do pass in the glands. To have, therefore, the portal blood perfectly pure, it should be taken below the glands, where the veins issue directly from the intestines.

Having described the precautions to be taken in collecting portal blood, M. Bernard drew some from an animal fasting. It is darker than other blood, the difference being very great when compared with arterial; though not so marked when compared with that from the hepatic veins, it was still very evident. It coagulates more slowly than any other blood, and the clot is diffluent, soft, scarcely solidified; it never presents a buffy coat, though it coagulates so slowly, a circumstance favorable to its formation. It absorbs a very great quantity of oxygen. In some experiments made the year before, M. Bernard observed that in this respect all bloods do not resemble each other. That of the vena portarum absorbed the most, from 20 to 25 per cent., that of the right ventricle, 18 to 20, of the jugular vein, 14 to 15, while the arterial blood only took up from 5 to 6 per cent. This property varies in different animals, the warm-blooded absorbing much more than the cold. Temperature also varies this absorbing power.

This is enough, however, on this point for the present.

The portal blood has to a very slight degree the property of becoming arterial in color. If venous blood be shaken in oxygen, it becomes red. It is supposed that when oxygen is absorbed, that the blood is red, and when given up that it is black, and this is generally true, though not always so; the vein of the kidneys carries red blood. The clot of the blood from the vena portarum never becomes red on its surface; that of the hepatic veins does: the portal blood is the only one that never does become red on exposure to the air. This blood contains more iron than any other, and the iron may affect the amount of oxygen absorbed, but cannot affect the color. This fact seems to show that not only the iron must exist, in order that oxygen be absorbed, but also that it must be combined with something in order that the blood become red. There is more iron when the blood enters the liver than when it comes out; there is some elimination of iron in the bile. In the liver the blood loses iron, and there is also a diminution in its property of absorbing oxygen.

As the portal blood possesses, then, properties very different from the arterial, it must have undergone a change in passing through the intestines. During digestion, other phenomena are seen; the blood in the vena portarum is much more abundant, and circulates much more freely. It contains more water, and many substances are

found to have been acquired. Saccharine matters can be there under several forms, as cane-sugar, grape-sugar, and lactic acid. Fecula can never be absorbed as such; it must be previously changed; it must be rendered soluble, so as to be digestible; it changes to grape-sugar. Cane-sugar is partly changed to grape, and partly absorbed as it is.

The portal blood is much less black during digestion than it was seen to be during abstinence, and its property of absorbing oxygen is diminished. Sugar has been shown by M. Bernard to diminish the property of the blood of absorbing oxygen.

In regard to the albuminous bodies, the direct proof of their existing in greater quantity in the portal vein during digestion than during abstinence, is perfectly impossible. With sugar it is very easy, but with these it is different, as albumen and fibrine are always existing there. M. Bernard, however, made the following experiments that are very conclusive on this point. When he placed in the intestine, albumen, either of the egg or of serum, it disappeared, and none was found in the excrements. When, instead of that, he put some into a vein, he always found it in the urine; so that here it played the part of a foreign body, and was thrown off as such. What difference is there in the two conditions? In the one, being placed in the jugular vein, it went at once to the heart, but in the other it went pre-

viously through the liver, and it is here that the necessary modification takes place. That it is not from any action exerted by the intestines, is shown by this, that upon throwing it directly into the vena portarum, none made its appearance in the urine. None is ever found in the urine when it is forced to pass through the liver before entering the arterial circulation. The same thing is true of cane-sugar, which is always found again in the urine, after being thrown into the jugular vein, yet none is ever found there if it be thrown into the portal vein. Now, if the chyliferous vessels absorbed albumen, they would empty it into the subclavian vein, it would go into the arterial system before passing through the liver, and would be eliminated as a foreign body. It must hence be judged that albumen is not absorbed by the lymphatics, but that it enters together with the sugar into the portal vein.

While the other *bloods* then remain about the same at all times, the blood in the vena portarum varies very much with what is eaten, and *above all* with the time. The blood in the arteries of herbivorous and of carnivorous animals is not essentially different; that in the vena portarum varies with the alimentation and with the period of digestion. Not many experiments have as yet been made, but they show changes not found in any other blood. This table is from observations made on a horse:—

	Five hours after eating.	Ten hours after eating.
Globules,	600·540	256·928
Plasma,	399·480	743·072
	1,000 000	1,000·000

The two principal parts of the blood, the globules and the plasma only are noticed, yet an immense difference is seen.

The alkalinity of the portal blood varies with the food, being less alkaline in the dog than in the rabbit or the horse. In the dog, the intestine is always acid; in the other two it is alkaline. The stomach in all animals is ever acid, while in the intestines the reaction changes with the food; when meat, being acid, and when vegetable, being alkaline. If to a carnivorous animal, a dog, for instance, you give potatoes, the reaction of the intestine becomes alkaline; so that the usual acidity is not owing to an acid secreted by the intestine itself, but to one developed by a chemical change undergone by the food. What becomes of the alkalies in the blood will be studied hereafter.

This blood of the vena portarum, thus constituted, must go into the general circulation, and in order to see the modifications it undergoes, it must be followed step by step on its passage. The first organ into which this blood is poured is the liver, for the portal system is *closed*, without any communication with any other.

What modifications then occur in the liver? They are of two orders: an augmentation or

diminution in the proportion of the elements previously existing, and the creation of new ones. Examining the blood before and after its passage, we shall see that some are found that did not previously exist; and among these, in the first rank is sugar. That it does not exist before, and that it must be formed in the liver, many and varied proofs show to be true. The formation of this new principle at the expense of another, must be studied. The fact is one that has been but recently demonstrated, and it shows the falsity of what had been previously maintained, that animals could not form *proximate principles*, but that they all came from vegetables.

In 1848, M. Bernard first made experiments to show that in all vertebrated animals, and even in the invertebrated, there is a source of production of sugar, independent of the nature of the food. He showed that this production is in the liver, and is independent of digestion, for though increasing during that period, it takes place during all. He showed that it takes place at the expense of the blood, which is incessantly traversing the liver, and that it is prevented by the destruction of the nerves supplying it. In animals, sugar is formed from the blood, by a special organ, under the influence of the nervous system.

The quantity of sugar formed at the time that digestion is going on, depends upon the quantity of blood that then passes through the liver, and it is for the reason that more blood is passing at that time, that more is formed.

When the liver does not act, as in severe fevers, &c., sugar is not formed, showing that the liver must be in a physiological condition of action.

In abstinence, the production of sugar gradually diminishes until death. After no more sugar is found, when the liver is no longer acting, although you give the animal food, it is too late, he certainly dies.

M. Bernard submitted eight dogs to different and exclusive articles of food. He divided them into two series: in one the experiments were continued for four days; in the other for eight. Of the four dogs in each series, one was condemned to abstinence, as a point of comparison; B. was nourished with fat only, 125 grammes being injected every day; C. with gelatine, also 125 grammes; and D. with fecula, 125 grammes. Each one had 300 grammes of water every day.

In the first series, at the expiration of the four days A. had 0·96 grammes of sugar, B. 0·88, C. 1·65, and D. 1·88. These are the quantities in 100 parts of blood, taken from the veins, just after traversing the liver. In the second series, at the end of the eight days, A. gave 0·13, B. 0·57, C. 1·35, and D. 1·50.

These experiments are very interesting, for they prove that the animals continued to produce sugar from gelatine and fecula, but that the fatty matters did not serve for that purpose, the quantity of sugar being no greater than when nothing was given.

We can say then that the sugar is formed at the expense of the azotized or saccharine matters. The effect we have just seen fatty matters to have, and the special apparatus which has been demonstrated for their absorption, all go to show that they do not pass through the liver. The ciphers for the quantity of sugar formed when gelatine and fecula are given, are about the same as the ciphers representing the normal quantity in the blood.

This sugar is chemically the same as glucose, but undergoes transformation with much more readiness. As the source of this sugar, fecula could only be called upon in animals having it in their food; carnivorous animals eating nothing capable of undergoing the transformation, nitrogenized matters must in them supply the material. In them, there is a diminution in the quantity of azotized matters in the blood, after traversing the liver, but a new principle, sugar, is found. As azote is not found in the sugar, it must have been separated in the liver, and it is found in the bile, by which means it is eliminated.

This sugar is intimately connected with the functions of life. The quantity is normally the same in all animals, there being about 1·50 per cent in the hepatic blood of both the carnivorous and the herbivorous. The greatest quantity M. Bernard has ever found was two per cent., and that was in a monkey who had eaten meat, butter, and carrots.

This quantity of sugar must be mixed with all

the blood of the body; already in the right ventricle, the proportion is much less, being only 0·69 per cent., as will be seen hereafter, in following the blood beyond the liver.

In vertebrated animals, the sugar, being immediately emptied into the vena cava, is spread at once over the body; in the invertebrated, in place of going away by the hepatic veins, it goes back to the intestines by the biliary duct, and is absorbed there by a special apparatus before going to the respiratory organs.

The quantity of sugar coming from the exterior, is very slight. When no saccharine matters are eaten, none is ever found in the portal blood, and when they are, you find only some traces of it; they may be taken up as lactic acid, &c. In the hepatic veins you have during digestion 1·50 per cent., and during abstinence one per cent., in *fresh* blood. The proportions given by Regnault are much more feeble; probably he was not aware of the great destructibility of this sugar. If it be not examined at once, a very great difference will be found; at the end of a few hours, in summer, when the destruction marches very rapidly, there is scarcely any. The sugar of diabetes is exactly the same as that of the liver, and it is also much more destructible than the others, being about twice as much so as ordinary glucose. The greater destructibility of the animal glucose, so to speak, over the vegetable, from which it cannot be distinguished by chemical tests, is shown by the follow-

ing experiment. Under the skin of two rabbits, whose urine, previously tested, showed no trace of sugar, he injected, by means of the canula of a trocar, solutions of these two sugars. The experiment might be performed by injecting them into the veins, but in this case it might be objected to the result that too much had been suddenly introduced into the circulation, and on that account some would be found in the urine. When they are introduced under the skin, and thus made to undergo absorption before entering the circulation, this objection cannot be made. In the case in which the animal glucose was injected, no sugar was found in the urine when it was tested by the liquor of Berresvil, in the urine of the other rabbit it was. As said before, one is about twice as destructible as the other.

The variations in the quantity of sugar have no relation whatever to those in the quantity of bile. Several modifications of the blood of the vena portarum occur in the liver, and they are independent of each other. It must not be thought that digestion, that is to say absorption, for absorption is the true digestion, commences immediately after deglutition. This absorption takes place several hours after eating. Five hours, then, after eating, when digestion is in full activity, we have the greatest quantity of sugar, and at this time, the flow of bile is feeble. It is when about ten hours have elapsed since eating that the flow of bile is greatest. This is perfectly conformable

to what is seen in invertebrated animals, in whom, as has been said, the sugar returns by the biliary duct to the intestines. In them, at the time of digestion, you see a colorless liquor flowing by the duct; when digestion is finished you see a colored: the first is sugar, the second is bile.

In making these experiments for the detection of sugar, M. Bernard was exceedingly careful. The vena portarum was tied, as has been shown above to be indispensably necessary, in order to prevent a mixture with the blood from the liver. The blood of the vena portarum was at once taken, and then he tied the venæ cavæ to prevent the blood of the heart from running into the hepatic veins, and also that of the inferior vena cava. At the same time can also be remarked the influence of the aliment upon the chyle in the thoracic duct, being milk-like when fatty matters are eaten, and transparent otherwise. The reactions of the stomach and of the intestines can also be noted. The cœcum always has an inverse reaction to that of the small intestines, the cause of which was thus explained by M. Bernard, in some lectures he had previously given on absorption. Generally more food is taken than is necessary for the nourishment of the body, and this portion, unabsorbed, after having undergone the action of the stomach, &c., arrives in the colon, where you find the excess and the refractory substances. In the colon they remain some time, and there undergo spontaneous putrefaction. In herbivorous animals, whose food

consists of sugar, fecula, &c., this putrefaction leads to the formation of acetic and other acids, and on account of this similarity of reaction, the colon was formerly considered a second stomach, because the experiments were confined to herbivorous animals. When, however, a carnivorous animal is taken, the substances in the colon beingalbuminous, their putrefaction, as every one knows, produces ammonia and ammoniacal salts, and the reaction there will be alkaline. This fact is so well known that the reaction of the colon can be changed at will by a change of food.

The other elements of the blood will now be followed in their passage through the liver. Two principal parts of the blood being the globules and the liquor sanguinis, their change in the liver will next be studied.

The globules are always augmented in quantity, as is seen by the following analyses made on horses. In one case, there were in the portal blood, 600·520 parts in 1000, and in the hepatic of the same animal, 776·396. A second experiment gave the same result, 572·632 before, and 743·400 after the liver. Another gave 256·928, and at the same time, in the hepatic, 518·476. A very great difference is seen in the last case, the reason of which is, that in the first two, the experiment was made five hours after eating, and in this one ten hours after, just at the time when the bile is being secreted in greatest quantity. At whatever time, however, the experiment is made,

you always find the same relation in the quantities.

These globules, then, must have *taken birth* in the liver, for although there are some before, there are more afterwards.

There are also physical differences between the globules that have traversed the liver, and those that have not. In the vena portarum they are broader, less thick, less rounded, and the spot resulting from their concavity is more distinct. After their passage, they appear to have lost in breadth, and gained in thickness. This difference is quite constant, and depends upon the production of sugar in the liver, the contact of a solution of sugar swelling the globules. When the animal loses the property of producing sugar, as by section of the nerves, you do not find it. The difference is therefore only accidental, depending upon the production of a new element.

The white globules in the portal blood are in feeble proportion, while in the hepatic, the quantity is enormous. On this account the serum of that blood almost always looks troubled. These white globules are at times united in a mass, at others they are disseminated; besides this, they present nothing at all peculiar. The difference in the quantity of iron before and after the liver, is very singular. In the portal blood, for 100 parts of dry globules, we have 0·213 of iron, while in the hepatic blood drawn at the same moment, we have 0·139. This shows that the iron disappears,

and it is very singular that the globules increase, and the iron diminishes. Another experiment gave 0·164 before, and 0·112 after the liver, and a third 0·201 and 0·140. This fact must be admitted as well established; but how can it be explained, for iron is one of the essential ingredients of a globule? We should know if the diminution of the iron does not come from the great quantity of white globules, for in these experiments the white and the red have been left together. As it is very probable that white globules do not contain any iron, to make the experiment more satisfactory, they should be separated from the red. M. Bernard said, however, that it could not be admitted that all the difference comes from the white globules. There is in the blood of the vena portarum an excess of iron, and as there is an elimination of iron in the bile, some would thus be thrown off. This iron comes from the food, and as it serves for the formation of globules, the iron eliminated in the bile would come from the destruction of the old. There is then a destruction as well as a formation of globules in the liver.

It was anciently admitted that the liver was the fabricator of the blood, and this would seem to be supported by what has just been said. However all that may be, we can only prove the fact of the augmentation of the globules and the elimination of iron.

For the fibrine in the vena portarum and the hepatic veins, Simon gives the following proportions in

1000 parts of blood: in the vena portarum 3·289; in the hepatic, 2·650. Another chemist gives the same. Lehmann went so far as to deny its existence in the portal blood. In the liver, the hydrocarbonaceous ingredients of the fibrine are used to make sugar, and the nitrogenized that are left, to make bile. Experiments show that the sugar and bile are in proportion to the fibrine destroyed. The fibrine of the hepatic blood gives to it properties that might be said to come from an excess of fibrine, namely, rapidity of formation, and firmness of the clot. It is much quicker and firmer than that of the portal blood, which forms very slowly, and is very soft. It will be seen, hereafter, however, that it is not the *quantity* of fibrine that determines these proportions, but that they are due to a chemical influence depending on the nervous system.

The fats are destroyed in traversing the liver. Simon and Lehmann have always found them to notably diminish. In 1000 parts of blood in the vena portarum, 1·103 parts were of fats, and in the hepatic veins, 0·640. This disappearance coincides with the formation of bile. When the sugar is formed at the expense of the fibrine, the nitrogenized matters left go with some of the fatty to form bile.

The albumen is also diminished in the blood; from 24·453 parts in 1000, it falls to but 16·703. Authors are not, however, agreed on this point, for Simon, who agrees with Lehmann about the

fats, says that there is an augmentation of albumen. This difference may be in accordance with some peculiarity of aliment, but as the analyses in both cases were made upon horses, it is more probably owing to a peculiarity in the mode of making the experiment.

The extractive matters are, for the vena portarum, 1·887; for the hepatic vein, 5·017. But what are these extractive matters? The name alone shows our ignorance.

The proportion of salts in the two different veins is 3·089 and 1·570.

These are the principal changes the blood undergoes in the liver. The disappearance of some substances is seen to be connected with the appearance of others, and the changes effected are seen to be in relation to what has before been said of the physiological properties of the two bloods; but this will be studied further hereafter. It has, however, been much discussed whether any of the elements of the bile are found in the vena portarum. Lehmann never was able to detect any, hence the liver is not an *excreting*, but a *secreting* organ.

The acids, choleic, &c., of the bile, are no longer found in the intestines; they disappear there, and are hence said to be there absorbed. If they are absorbed, it is after being changed, so as to be no longer the same substances, and this manner of being absorbed, this change of bodies while undergoing absorption, must be taken into account. It has been said that certain substances,

alcohol for instance, can be absorbed unchanged, and act at once upon the liver, but it must be shown that they are found in the vena portarum.

THE TEMPERATURE.

In some organs the blood warms; in others, it cools. In the liver it warms, as M. Bernard has shown by many experiments. These consist in introducing a thermometer into the blood as it enters and issues from the organ. There is sometimes a difference of 1° or more. The substances taken into the intestines cause this diversity; for, give *cold* water, it is absorbed as such, and the blood is consequently much colder. Normally, however, under all circumstances, the temperature of the hepatic blood is higher than that of the portal. When you divide the nerves, and thus prevent the chemical changes from taking place, the blood is not warmed in the liver.

This warmth of the blood has much to do with its coagulation, as is seen in cold and warm-blooded animals, and also at the entrance and the departure from organs.

The blood undergoes these changes by its contact with the tissue of the liver. What is it, and how do these modifications occur? The fundamental tissue is the cells, and around them are the vessels and nerves. The cells are disposed as is well known: each lobule is a mass of them,

and each cell is granular and with a nucleus. In the centre of the lobule is the hepatic vein, and on the periphery is the portal; the entering blood is then on the circumference, and the issuing in the centre. The blood on its passage must therefore come in contact with a series of cells, and these cells make it undergo a series of modifications. The biliary ducts arrive to each lobule like the divisions of the vena portarum, and until now it has been impossible to tell the relations of the ducts with them. Their extremities are open, not terminating in a cul-de-sac, as in all the other glands. It is seen from the distribution of the vessels that the sugar must be forced from the circumference to the centre, and the bile from the centre to the circumference.

There are besides a great number of nerves accompanying the vessels and ramifying with them. It is impossible to follow them as far as the lobules, but upon their division the functions of the liver cease at once.

As a last question, How does the blood circulate there? The liver receives a very small artery, evidently only for its nourishment, as the lungs do the bronchial. There is a vein ramifying in a manner inverse to that of the venous system, dividing again and again into branches; one end of it acts as an artery, the other as a vein, for the hepatic is a true vein. Evidently, then, you do not have the usual conditions in the hepatic circulation. As a general rule, in an organ, you have an artery in

which the blood is pushed by the impulsion of the heart. This impulsion is here replaced by the abdominal pressure, taking place by the recti muscles approaching the vertebral column, and by the diaphragm. There is, moreover, in the liver itself, a pressure. There is there an active movement, coming from muscular fibres that are principally seated in the hepatic veins. They are found above all in the horse. Only a few of these muscular fibres are circular; they are longitudinal in the hepatic veins, and it is evident that, upon their contraction, their two ends approaching one another, the liver would be contracted in such a way as to expel the blood it contained. It is seen, therefore, that there are two actions: one the abdominal pressure, causing the blood to flow into the organ; and another, the contraction of a longitudinal muscular tunic in the veins, which exercises a pressure, having for its object the expulsion of the blood from the organ.*

In order to terminate the history of the portal blood, we must examine the blood coming from organs neighboring to the intestines and flowing into it. We must distinguish in the portal blood the elements that constitute it; and we must therefore study the organs whence they come. We must see if some organs, the spleen, the pancreas, and the mesenteric ganglions, do not

* See Appendix, Note C.

influence the blood contained in the vena portarum. The spleen will first be examined, then the pancreas, and then the mesenteric glands; and afterwards, by comparing the blood of these several organs, we will have what we are seeking.

The spleen receives large bloodvessels; an artery conveys the blood to it, and a vein carries it back, after having undergone certain modifications. Simon and Jules Béclard experimented, but they compared the venous blood of the spleen with that of the jugular vein, when they should have compared it with that of the artery. The splenic blood contains fewer globules, and as the jugular does not contain so many as the arterial, of course, if compared with the latter, the proportion would be still smaller. The albumen is increased; the fibrine remains nearly the same.

M. Bernard gave the following analysis, which is about the same as that of all others:—

	Jugular vein.	Splenic.
Water,	782·95	786·91
Globules,	128·44	113·53
Albumen and Salts,	84·45	94·94
Fibrine,	4·16	4·60

The difference in the quantity of water is very trifling. The diminution of globules is constant, and, as is always found in such cases, there is an augmentation of the albumen. The form of the globules remains the same.

In the parenchyma of the spleen are found

small cells, containing four or five globules of blood; and this has caused it to be maintained that the globules were fabricated there, which cannot be, from what has just been seen, namely, that there are fewer globules after the spleen than before.*

The splenic blood when drawn off is seen to coagulate perfectly well, the globules precipitating, &c., but when the clot is separated from the serum, a phenomenon is observed that shows a great difference between it and other blood: this serum alone coagulates in its turn, and in it a white clot forms and a new serum, and this sometimes coagulates a second, and even a third time.

Béclard finding nothing like this in the jugular vein, &c., thought it to be peculiar to the splenic venous blood, but he was mistaken. Magendie has spoken of this phenomenon, which he calls *secondary coagulation*, and has shown that the blood of the vena portarum can present it. But the lymph also presents this phenomenon, and the liquid of the peritoneum—the humidity—which in full digestion, is always thrown out there in considerable quantity, to be taken up again when digestion is over. The coagulation of these liquids is repeated again and again, so that the quality possessed by splenic blood is a quality of the lymph. It might, therefore, be said, that the

* See Appendix, Note C.

phenomenon exists in the splenic blood because it contains much lymph.

There is another property that exists not only in the splenic blood, but in that of all the veins emptying into the vena portarum, from other organs and from the intestines. This is, that its fibrine dissolves in warm water after a certain time; and this phenomenon takes place in the blood from all parts of the system when the animal has been much bled.

The spleen has been examined by persons who have studied its blood, and that of other parts of the body, and they have judged that it could serve different purposes in traversing other organs. It has been thought by some that it could pass to the stomach, and go to form the gastric juice; but this is an error, for there is no communication. Experiment has shown the falsity of this theory, for in a dog whose spleen had been removed, M. Bernard found the gastric juice to remain the same. It might be supposed that the removal would have some effect upon the pancreas, but it has not, its secretion continuing as before.

The splenic blood has been said to serve to fabricate the bile. This theory is false, as is shown by a dog with a biliary fistula, whence the bile flows as it ever did, and whose spleen had been extirpated. No one of these three secretions, the gastric, the biliary, and the pancreatic, is changed, then, by the splenic blood.

It has been said that it is the organ where the

blood-globules are made; and the theory supported by the fact, that they only exist in animals having a spleen, in vertebrated animals. It has, on the other side, been said to destroy them; and this theory supported by the fact, that they are in diminished quantity after passing through the organ, and in it are found cellules containing globules, which it was maintained are there destroyed and thrown into the circulation. If, however, it either fabricated them or destroyed them, its extirpation would influence their proportion in the blood; but although it has been done many hundreds of times, it has never been shown to have any effect on its composition. Lastly, and the idea is a very old one, the spleen has been considered to be a kind of sponge, acting as a diverticulum in the circulatory apparatus. The idea is ill-founded, in the sense that it holds blood in abstinence to be given up while digestion is going on, for the spleen always contains most blood at the time of digestion.

It is a very interesting fact, that all parenchymatous organs contain at certain times far more blood than at others. In the liver, &c., this blood only enters by degrees; and they are gradually relieved as the blood diminishes in quantity by the perspiration, the urine, and the other secretions. Hales experimented upon this *aptitude of imbibition*, by introducing warm water into the veins. The animals experimented upon presented nothing externally, but when opened, the liver and

spleen were found much distended. The first water injected goes to them; and if the injection be pushed further, you see infiltration of the exterior organs, and of the lungs. When a great quantity of water is drunk by an animal, as by a horse, for instance, who may take seven or eight bucketfuls, it cannot at once enter the general circulation; it localizes itself in the parenchymas, and enters by degrees as the blood throws it off by various organs. The spleen enjoys this aptitude of imbibition, and the liver also; and what is remarkable, these organs have muscular fibres. These have been spoken of before as existing in the liver, and the spleen possesses them also. Some substances, as strychnine, have the property of causing the spleen to contract with great force; and it is possessed also by camphor and some other substances. Their effect is to express the blood from that organ, as from a sponge. Electricity also possesses this property, as has been shown by some experiments first made in Germany. M. Bernard has repeated these experiments at the Society of Biology, and its contractions were very evident. This contractility is owing to muscular fibres, a sort of contractile cells, a kind of *passage* from primitive cells to the muscular fibre.*

In order to study the blood going to and coming from the pancreas, it would be necessary to study it upon animals of a very large size, and M. Bernard said he knew of no experiments.

* See Appendix, Note D.

The mesenteric glands are very numerous and have many bloodvessels, and it has long been supposed that a change took place there between the blood and the lymph. When the chyle is examined after passing through these glands, you find it to contain blood-globules. Do they come from the blood in the ganglions, and has the blood in turn received nothing from the chyle? It is very probable that it is from these mesenteric glands that the white globules come, which are so abundant in the portal blood. This is difficult to prove, for these veins empty into the vena portarum so high up, so very near the liver; but it is very probable indeed that the white globules come from these glands.

The whole blood from the intestines and their annexed organs has now been studied. While the blood from the rest of the body varies very little, it has been seen to vary here considerably, both with regard to other blood and with regard to itself. In abstinence there is one change, and in digestion another. The blood seeks in the intestines, as the augmentation of the albuminous matters shows, materials for its nourishment. This albumen, traversing the liver, changes to globules, which are more abundant here than elsewhere in the blood.

To resume, we may say that in this blood that has traversed the liver, we have a blood that differs considerably from that of other parts of the body. There are more globules, red and white, and they

are not changed as those of other parts by contact with the air; there is more sugar, hence greater density, and more extractive matters, which in other organs are transformed to other elements of the blood; and lastly, the fibrine, though about the same in quality, is soft, and soluble in water. This blood cannot therefore be considered a *finished* blood, a *perfected* blood; before becoming so, it must be changed.

Just where this blood, elaborated in the intestines, is about to be thrown into the general circulation, there is an organ, the kidney, and the influence this organ has upon the blood, must be examined before proceeding to the lungs.

Except in mammiferous animals, there is a portal vein for the kidney, as there is for the liver; in them it disappears, but the *vestiges*, as it were, are found.

The kidney has for its office to eliminate certain substances from the blood. Its blood has been analyzed, but less often than that of other organs, and a great difference is shown. In the first place, the venous blood is red, as M. Bernard showed with some he had just drawn from a horse, and what is strange, it changes black with much more difficulty than arterial blood. Arterial blood drawn from an animal after a time becomes black, but the venous blood from the kidney does so much more slowly. Why is this color so red? That from the hepatic veins in the same animal, known to be from there by its containing sugar,

although he had not eaten for several days, and also that from the jugular vein, which contained no sugar, were black. The renal venous blood contained no sugar. The kidney must have had this influence on the blood, giving it a red color, so long persistent. When venous blood is placed in contact with the air, two things take place: one is, that oxygen is absorbed, the other that it becomes red. These two things do not depend upon each other; for it was shown that the portal blood absorbs much oxygen, and does not become red. M. Bernard said he could not say to what this quality was owing, in the renal blood, and he dismissed the question by promising to tell in his next lecture, how much oxygen this blood absorbed, an experiment that had never been made; but he never referred to the matter again.

This blood, as Simon has shown, and he alone has made an analysis, comparing it with the arterial, contains no fibrine. These are the tables he has given :—

	Renal vein.	Renal artery.
Water,	778·000	790 000
Solid matters,	222 000	210 000
	1000·000	1000.000
Fibrine,	000 000	8·200
Albumen,	99·430	90 300

There is less water in the vein, for the urine carries it off, and the solid matters are in greater proportion, because there is less water. If the

fibrine be added to the albumen, in the arterial blood, it equals the albumen in the venous, as if the fibrine had been transformed into it.

Blood with no fibrine can coagulate, and there is no relation between the two that is constant. Coagulating matters must be distinguished from fibrine. The renal blood can coagulate, but its coagulum is very soft. This property of coagulation will be seen to be related to the action of the nerves on an organ. It is known that if the sympathetic nerve be cut in a portion of the body, that there will be an acceleration of the circulation, and moreover, the blood will be modified. In a dog, to cut the sympathetic, the pneumogastric must be cut, but in a horse it can be cut alone, and M. Bernard has twice made the experiment on that animal.

Among the modifications in the blood drawn away, the most striking were those in its coagulation. Before the section the blood did not coagulate for an hour, for in the horse the blood coagulates more slowly than in any other mammiferous animal. The blood drawn fifteen minutes after the section was perfectly coagulated in four or five minutes, and the white coat was not formed, which is always seen in the horse, where, from the slowness of the coagulation, the globules have time to separate themselves. As to the fibrine, M. Bernard has always found that here, where the blood coagulates so soon, after the section of the sympathetic nerves, it is always dimi-

nished.* We have just seen that the renal blood, that forms a coagulum very well, does not contain any fibrine at all.

The albumen augments in the renal venous blood, and M. Bernard is disposed to believe that it is owing to a transformation of the fibrine; for, looking at the ciphers in the tables, we see that it is just what is wanted to compensate for the difference in the albumen.

There is a difference of temperature, the venous blood of the kidneys being hotter than the arterial. At the point where the renal and hepatic blood meet in the vena cava ascendens, the temperature is the highest in the body; the blood in the vein there is 2° Centigrade warmer than that in the aorta alongside. This blood mixes in the right heart with that of the descending vena cava, whose blood is colder than that of the artery, but the blood of the right is nevertheless warmer than that of the left. This excess of temperature in the veins is evidently one of the causes of animal heat. This varies, oscillating from 38° to 40° Centigrade, and these oscillations are caused by certain circumstances. Suppose an animal to be motionless, his temperature is found to augment after each digestion; and evidently, after each digestive phenomenon, the liver and kidneys are forced to work harder. Again, this augmentation is always four or five hours after eating, and this is precisely the time at which

* See Appendix, Note E.

these organs are acting. About that time is required for the digestion of substances, there being a difference in the articles used as food, cooked meat, for instance, requiring four or five hours, while uncooked requires six or seven. But the kidney, like many others, is a *mixed* organ. This elevation of temperature must be caused by chemical actions, but there are besides, as the influence of pressure shows, others that are purely physical. It results from this that we must make a distinction. We have the urinary excretion and the modification of the blood, and M. Bernard thinks that there is no relation whatever between the two.

A pressure takes place in the kidney after digestion, a double pressure, and this produces much more urine than when the pressure is but simple. There is in some animals, as was said before, a true portal vein in the kidney; in man, there is none, but some actions take place that are entirely analogous to those occurring in a vena portarum. At a certain moment of digestion, a very large quantity of blood is given to the liver. In some animals, as, for instance, the rabbit, the too great filling of that organ is prevented by large collateral veins, that go to the inferior vena cava. At this moment there is a kind of stagnation of blood taking place in the inferior vena cava, below the point where the hepatic veins empty into it, and in animals in which this stagnation is very marked, the hepatic veins have very powerful muscular fibres. The blood being there arrested, the action is driven upon the kidneys, and in some animals

is prevented from going down below the renal vein, by the presence of valves immediately below it in the vena cava; in the horse, there are four such valves. Now when blood is thus driven into the kidneys, what happens? It was seen before, that whenever you hinder the flow of blood in the veins, you increase the pressure in the arteries, and this augmented pressure must increase the flow of the urine. At this moment there is not only more urine, but it suddenly changes in character. All know of the troubled urines of digestion of the horse, the rabbit, in short, of all herbivorous animals, of all whose intestinal system is very much developed, who have a long digestive tube. During abstinence from food, their urine is not troubled.

There is, then, in the renal circulation, this peculiarity, that under some circumstances, above all in mammiferous animals the taking of much liquid, there is a reflux from the vein, and this kind of reflux, of stagnation of the blood, increases the pressure, and under that influence more urine is secreted. It would seem as if at such a moment the circulation in the lower limbs would be impeded, but to avoid that, there is a circuitous circulation, a special circulation, which takes place by the azygos vein, connecting the lumbar veins with the superior vena cava. During abstinence, the blood circulates freely, and the circulation of the kidney is the same as that of other organs.

This peculiarity of the circulation explains how

the urine of animals changes, and that a distinction of animals cannot, as has been attempted, be made from differences in the character of their urine. The urine of herbivorous animals is just the same as that of carnivorous, when they are fasting, for at that time the circulation in the kidney is the same in both, and it only produces urine from arterial blood. The renal circulations being identical, the urines are also, that is, they are both acid, and contain much urea. Now if food be given to both animals, according to their natures, the urine of carnivorous animals will remain about the same, while that of herbivorous will become by degrees alkaline and troubled, and this change will take place just at the time that there is a change in the renal circulation.

M. Bernard, in order to show this, took two rabbits, one fasting, the other in digestion, and their urines were found essentially different. In the one that had fasted, the litmus paper was very strongly reddened, while in the other, the reaction presented a different character, the paper remaining blue, and yet the urine was still clear. The urine was clear, because there were bicarbonates, that held the carbonates in solution. The *troubled* urine is not, then, as fixed a character as the acidity and the alkalinity. The urine of fasting gave no effervescence when an acid was added, while the other gave a great deal. It must be decided, then, that the urine is the same in all animals during abstinence, but that if different things be put into the stomach, it is clear, after what has been said of

the renal circulation, that there must be a change. We cannot, then, accept the dictum of authors, that herbivorous animals have alkaline urine, and carnivorous, acid.

How do these carbonates form in herbivorous animals? In abstinence the urine is acid, and in digestion alkaline; if the two previously filtered be mixed together, a clouded urine will at once be found. It might be supposed that the bladder of the rabbit received two urines, and that some of the urine of fasting having been left there, a precipitate takes place when that of digestion arrived. M. Bernard has experimented upon this point, making an opening into the ureter of a rabbit, so as to receive the urine before it reached the bladder. He found it to be clear in fasting, and in digestion to be troubled, just as before. When, however, he took the crystals of the carbonate of lime, and injected them into the artery of the kidney, he found they could not pass, showing that their precipitation must have taken place after leaving the blood. The fact of their being found in the ureters shows that they are not formed in the bladder, as had been supposed, but that they must be formed higher up; and yet the last experiment shows they are formed after leaving the vessels of the kidney. It must therefore be admitted that there are probably two secretions in the kidney, that they meet there, and that the precipitation takes place in the pelvis of that organ. At times, as in the experiment just performed, it happens that the urine is per-

fectly alkaline, and yet perfectly clear; this, however, is very rare.

When the artery alone acts in the formation of urine, it is acid and clear, and when there is a reflux of the venous blood into the kidney, it is alkaline. These changes exist in carnivorous animals at these moments, but owing chiefly to the food, they are less marked than in the herbivorous. In full digestion, though the reflux exists to a much less degree, their urine becomes alkaline. But in them this happens their aliment is nitrogenized, and furnishes ammonia, and their urine is alkaline from the carbonate of ammonia. At the instant it is passed, their urine is alkaline, but in a few moments this volatile substance has all gone, and the urine becomes acid. M. Bernard has repeatedly shown this, the litmus paper remaining some time unchanged, and then becoming red, when the ammonia had volatilized. In all animals, then, the urine is modified during digestion, and the modification depends on the food, in herbivorous animals there being at that period much magnesia and lime, and in carnivorous, ammonia.

Many other substances are eliminated by the kidney. This organ is charged to cast off from the blood all substances that are in excess, albumen, sugar, the chlorides, all most essential elements of the circulating fluid, but which must be maintained there in certain proportions. It is the kidney that is charged with this. The kidney in its part of excreting organ is endowed with such a sensibi-

lity that it only eliminates those substances when they exist in a certain quantity. For instance, sugar, at the period of digestion, goes there, but is not eliminated, though some does go there, for it is found in the arterial system. If, however, there is an excess in the arterial system, it is eliminated. The same is true of the chlorides, and of albumen. Why is this? Has the kidney a certain intelligence? Evidently this action of the kidney does not belong to that organ, but belongs to the blood itself. The sugar in the blood must not be considered as free, but as united to fibrine, or to some other organic principle. When too much is in the blood, it is not thus united, it is free, and then the kidney eliminates it. This is proved by the fact, that you can cause the elimination of these substances by modifying the blood, by changing the proportion between the albuminoid bodies, the salts, and the water. Without doing anything else, inject water into the venous system, and after that you will constantly find albumen in the urine, merely because you have changed the relation existing between the elements of the blood. If more water be injected, not only albumen, but blood-globules will come out. When we eat, we take much more than is needed, but the blood must be fixed, and it is maintained so by the elimination going on in the kidneys.

So far, only the blood returning from the organs of nutritive life has been spoken of, and before going to the heart, it will be necessary to

examine that from the other parts of the body. Before doing so, however, there is a property coming from digestion that should be mentioned, which arises from a mixture with the chyle. Dark, and with limpid serum before, after this addition it has a *dirty* color: it looks like pus mixed with blood, and could be taken for such. This character should only exist for a short time, and it does disappear after the blood thus mixed has passed the lungs. It is a character that should only exist between the point where the chyle is emptied, and the lungs. In some cases, however, the chyle is found in the blood of the neighboring veins; as is seen, for instance, on opening the jugular vein of an animal, while he is making great exertion. These efforts prevent the flow of blood in the jugular vein; it is stagnated, and at the same time the thoracic duct continues to pour out its chyle, and more rapidly than before, because the efforts cause pressure upon the contents of the abdomen. This chyle is obliged to make itself a place, and flows with the blood out of the opening in the vein, and thus what is called a *white bleeding* is caused. Blood having a chylous appearance, can be found elsewhere, and chiefly during digestion. Cases have been cited, and M. Bernard has seen such himself, where in bleedings of precaution, in the arm, that were performed soon after eating, there was an appearance precisely like blood and milk. It is exceptional to see this chylous blood in man, because he is not often bled in *full* digestion, but this character of

the blood can always be had in animals by choosing the proper time. When M. Bernard said that the chyle disappears in the lungs, he intended to mean, provided there was not too much.

The blood in the general venous system will now be examined. This is the blood that first was known, for it is what is extracted in blood-letting. An enormous quantity of analyses have been made, so numerous and so conflicting that it is very difficult to choose among them. One fact can be determined, that the differences between different individuals are far greater than the differences between arterial and venous blood in the same one. It cannot be said that there is a change in the fibrine, and while some say that the globules are larger in the venous blood than in the arterial, others deny it.

In any case, the superficial venous blood should not be considered absolutely as the venous blood, because the blood of the portal vein mixes with the rest before coming to the heart, and to have venous blood, it should be taken in the right ventricle. At the elbow, sugar and fatty matters are not generally found, and in the heart they are.

Until now analyses have never been made to see if the blood from the skin is different from that coming from the muscles. This could easily be done in the large herbivorous animals, where there is a large cutaneous vein in the abdomen.

It must be known that *the venous blood* is only to be found in the right ventricle; blood with sugar

and with fatty matters in suspension. The *complete venous blood* is only found there, because in the lungs the sugar leaves, and the fatty matters are modified.

A very singular phenomenon in some animals is the property possessed by the blood of coagulating with greater or less facility. The venous blood, as a general rule, coagulates more slowly than the arterial, and in some animals so slowly that the globules have time to separate, and a white coating of the fibrine alone is formed. That this is not owing to the aliment, is seen by comparing the venous blood from a horse, coagulating in an hour and a half, with that of a sheep, which had eaten the same, coagulating in two minutes. This is not owing to the fibrine in it, but to certain nervous influences. Taking the same horse, and cutting his great sympathetic nerve, when blood was drawn from the part of the body influenced by the divided nerve, there was no buffy coat, and it coagulated immediately.

Venous blood coming from the sources before indicated, is destined to traverse the lungs, and then circulate in the economy. The blood does not circulate in the veins, from the same influences as in the arteries; the causes of the venous circulation are more multiplied and are very diverse. The causes of the circulation in the arteries have been already spoken of, the impulsion of the heart, and the elasticity of the arteries, and neither of these causes can act, after passing

the capillary system. The walls of the veins distend very easily, and return with difficulty to their previous state; the venous system in general is here spoken of.

These causes should be examined in the extremely small veins and in the large. In the first place the position of the part; always when a part is so placed that the blood must ascend, the circulation is more deficient, as can be seen in the hand. In the horse, an animal with a long neck, by introducing a barometer into the vein, the much greater difficulty of the circulation when the head is down is very apparent. Again, muscular contractions, and this is a cause that we can also perfectly well act upon. In the case just mentioned, something to eat being given to the horse, at each movement of his jaw, the great influence of the muscular contractions was very evident. The muscles push out the blood just as the heart does.

The impulsion of the heart is also a cause of the venous circulation, but an indirect one. The blood of the veins cannot retrograde into the arteries, but that of the arteries can be pushed into the veins. It must therefore be admitted that the venous circulation can be aided by the arteries. The venous pulse is but a reflux of blood, owing to the position of certain veins, from the right ventricle. This is easy to comprehend, but it is not what M. Bernard is speaking of. He means a

pulsation, from the left ventricle, transmitted from the arteries, through the capillaries into the veins. This pulsation has never been seen, except in patients attacked with very severe affections, in persons in a state of adynamia, and its cause has been much discussed. The most plausible explanation is, that it depends on a paralysis of the capillaries. The contractility of these vessels is constantly acting against the impulse from the heart; this tends to push them open, they contract, and thus the blood is forced into the veins; but when they are paralyzed, this impulse is continued, and it shows itself in the veins. Moreover, in cases of venous pulsation, you always find in the same individual, other paralyses, as, for instance, of the intestines.

In addition to these, position, muscular contraction, and the indirect influence of the heart, there is also another cause, depending on the lungs, which acts upon the blood in the large veins. At the moment of each respiration, the blood rushes into the chest, a vacuum is formed, and the blood rushes to fill it; there is a *dragging* of the blood. Every one knows the accidents resulting from the opening of a vein, and the *drawing in* of the air. The air is precipitated into the heart, and if it be in sufficient quantity, death is produced. This death is altogether mechanical, being caused by a kind of froth, that stops the capillaries of the lungs, and acts just as if a ligature had been placed on the pulmonary artery. This kind of

aspiration has been thought not to act very far, and not to reach the extremities; but in his experiments, M. Bernard has found it to go much further than has been thought; not certainly to the superficial veins of the limbs, but, on account of their capability of remaining open, to the veins of the brain. M. Bernard removed the occipital bone of an animal, and opened the sinus. Bichat had done this, and thought the animal died from the hemorrhage, but M. Bernard found he died the sooner the more he struggled, and examining the lungs, he found the froth arising from the admission of air, and this froth could be followed up to the opening in the sinus. He then tied the four jugular veins, in order to prevent the air from passing, and still the animal died. But on examination, the froth existed in the lungs, and searching, he found the air had passed through the vertebral veins and the azygos, into the heart. These experiments show clearly that aspiration acts on the cerebral veins, and deep inspirations, by emptying them, must then be a great means of rendering more active the circulation in the brain. The cause, the manner, and the pressure of the venous circulation are, then, very various in different veins, and in different conditions.

To terminate the subject, the changes taking place in the lungs must now be considered. It is impossible for an animal to live if the modifications which the blood undergoes in the lungs be prevented, and on this account these organs have been

regarded as the organs of hematosis, *par excellence.* These changes have, in consequence of this opinion, been very often examined, and we must now study them, in order to see what things occur so very important.

The first difference noticed after leaving the lungs, is that in the color, which has at once become red, from being black in the right ventricle, or often grayish from the contents of the thoracic duct. To explain this change, the oxidation of the blood, or more strictly speaking, of the iron it contains, has been brought forward. This red color has been given by Bichat, as characteristic of arterial blood, but it has been seen above that the blood might possess that color, and yet be unfit to maintain life, as after the action of the carbonic oxide, and it was seen also that the blood of the veins of the kidney was red. It cannot therefore be believed, that it is the color that gives this character, since we know that it is given by many different qualities. This change of color has a relation to the absorption of oxygen, for blood abstracted from the veins, and exposed in a vase to the air, becomes red. This coloration thus produced in the lungs is caused by the action of oxygen upon the globules. There are two principal theories, one that oxygen makes them red, the other that carbonic acid makes them black. The arterial blood holds more oxygen, the venous more carbonic acid, and from this comes the difference in their colors.

When you take arterial blood, and add to it just as much carbonic acid as the venous contains, it is not made black, showing that something more than this, the mere addition of the gas, is needed. It was then said, that it was not the presence of carbonic acid that caused blackness, but the absence of oxygen; that in their ordinary condition the globules were naturally black, and that they became red by the influence of the oxygen absorbed. When, in the round of the circulation, this oxygen was given up to the different tissues, they took again their natural color. According to this supposition, the black, venous color, is the natural, normal one. It can certainly be said, in support of this, that the redness is not necessary, for during fœtal life, the red blood does not exist. It is only when respiration commences, when oxygen comes in contact with the globules in the lungs, that vermilion blood exists.

The same gases, then, are contained in both bloods. Their proportion to the rest of the blood is seen in the following tables, the absolute quantities not being given.

	Volumes of gas.	Volumes of oxygen.	Volumes of carbonic acid.	
Arterial, . .	1051 . . .	250 . . .	not given.	Horse.
Venous, . .	794 . . .	128 . . .		
Arterial, . .	1163 . . .	279	703	Calf.
Venous, . .	716 . . .	95	556	

The arterial blood is seen by these tables to contain much more oxygen. M. Bernard declared

that for the carbonic acid there was a mistake in the ciphers, for according to them there would be more in the arterial blood than in the venous.* There is always more carbonic acid in the venous blood.

As to the nitrogen, the relative quantities have not been determined.

The blood, then, after its passage through the lungs, presents differences in color and in the quantities of the gases it contains. There are also changes in its composition, in the globules, fibrine, and albumen.

It has been said that the arterial blood contains more fibrine, but this is evidently but a change in its proportions, and must not be considered as a production of any new fibrine. Suppose the water in the blood to be diminished, the proportion of solids must be relatively increased. It is perfectly well known, that water is thrown off from the lungs during respiration. It can, however, happen, that in place of water being thrown off in the lungs, it can enter there ; all this depending on the quantity primitively existing in the blood. When water is injected into the veins, as Magendie has shown, the quantity given off by the respiration is much increased; but suppose the animal has

* M. Bernard neglected to observe that the quantities given are those found in different volumes of blood, and that in reality the quantity in the arterial blood is much less. If the quantity were but equal to that given for the venous, instead of being 703 for 1163 volumes of blood, it would be 901.

thirst, that he has had no drink for a long time, he then absorbs water by the lungs, and there is more after than before.

Not only water is thrown off, but this water contains a peculiar animal matter, that putrefies with great rapidity. If a sponge, after a most thorough cleansing, be hung up in an apartment where many persons are assembled, and after remaining some time, the water it contains be pressed out, this water will be seen to putrefy very soon, and to become very offensive.

The animal heat has been derived from the respiration, and connected with the modifications then undergone by the blood. After the section of the pneumogastric nerve, the animal heat diminishes, because it was said, these changes are prevented. Again, it was said, the diminution or increase of the respiration, is attended by a corresponding diminution or increase of the heat, as is seen in birds, in hibernating animals, in impediments to the respiration, &c. But the facts, which in themselves are true, must be interpreted differently. Experiments have also been made to see in which ventricle the blood was the hotter, for there the state of the blood, before and after passing the lungs, is represented. These experiments are very difficult to make, for the mutilation is so great, that death is almost instantaneous, so that their observations were made on the dead and not on the living animal. They were, however, again and again repeated, and the general conclusion was, that the tem-

perature was elevated by its passage through the lungs, and this was in accordance with the prevailing theory. These experiments were made everywhere, and this interpretation reigns generally now in science.

But it was said above, that the maximum of the temperature in the human body, was found in the inferior vena cava, and as it empties into the right side of the heart, the heat should be greater there. It is on this side, in fact, that the temperature is the higher, and we must renounce the ancient theory, founded, it is true, upon facts, but we must properly judge the facts. The theory of Lavoisier, that heat was produced in the lungs, was modified before the experiments of which M. Bernard is about to speak, for it was shown that the production of carbonic acid did not take place in the lungs; that there was not a combustion *on the spot*. The combustion occurs in the capillaries of the body, and there the heat is evolved, and it takes place by means of the oxygen that enters by the lungs. In the capillaries of the lungs themselves, oxygen is simply taken in, and carbonic acid given out.

The results of these experiments are owing to the more rapid cooling of the thinner side of the heart, and they only show that the left ventricle does not cool so quickly as the right. Put a thermometer in each ventricle, and put the heart into water at 40° Centigrade, they will stand at 40° also; then take it out, and leave it in a

temperature of 16°, and in a short time there will be a difference of 6° in the two ventricles. Kill an animal as quickly as you may, it requires time to open largely the thorax and make the observations, and during this time the parts are changing their temperatures.

Although it has already been seen that there is a difference between the vena cava and the aorta, the vein being the hotter, the experiment must be made upon the ventricles, and, as is very evident from what has just been said, during the life of the animal.

M. Bernard generally performs his experiments upon dogs, but for this one, where the thermometer must be introduced by the brachio-cephalic trunk into the left ventricle, that animal is unsuitable, on account of the shortness of his neck. The difficulty of the experiment is here, in the introduction of the instrument a long distance through a narrow arterial tube; as far as the veins are concerned, there is no trouble at all. He, therefore, for this purpose, chooses a sheep, where it can be done very much more easily. The animal breathes as usual, the walls of the chest being left intact, while you can introduce the instrument as far as the ventricles. M. Bernard had repeated this, but a few days before his lecture, making thirteen experiments, and always finding the right ventricle the hotter of the two. He used a thermometer of the greatest delicacy, and as no two are ever the same, one being more easily in-

fluenced than another, he always used but the same one, plunging it alternately into the right or left side. At one time he commenced with the vein, at another with the artery, but always with the same result; the blood was always warmer on the right side.

We must conclude from this, that the animal heat is not derived from the lungs.

The part, therefore, which the lungs perform in hematosis is not so great as was supposed, and we must go back to Galen's idea, that the liver was the great fabricator of the blood.

M. Bernard then stated he was about to perform an old experiment, that Galen himself had performed,—the section of the pneumogastric nerve. When they performed this experiment, the ancients only occupied themselves with the larynx, but he wished to examine the effect upon the lungs. The first effect of this section is a diminution of the number of respirations in a given time, and a second one is an augmentation of the beatings of the heart; these two, then, are not constantly related to each other.

The first dog brought to him for the performance of this operation, he sent away on account of its being too young, as in such cases the animal is stifled at once, on account of the peculiar formation of the larynx. At that time, the arytenoid cartilages are not fully developed, and the glottis tightly closes, while in older animals the cartilages are more resisting, and although, as in the other

case, the anterior part of the glottis is in contact, yet the posterior part remains open. Hence the different effect of the section in young or old animals; and in children and adults the same thing occurs.

M. Bernard had, therefore, an older dog brought to him. His respirations counted from 28 to 30 in the minute, and after the section he thought they would be 16 at first and afterwards gradually diminish. The pulsations of the heart counted 80, and these would be so increased as to become countless. The animal was howling; when one nerve was divided, the voice was altered, and when the other was cut, it was instantaneously abolished. The animal had been eating, and vomited after the operation, which he would not have done had the stomach been empty. The respirations could not immediately be counted on account of this vomiting, but when it had ceased, they amounted to but 8, at the very most to 10, in a minute. While this great reduction had taken place from 30 to 10, the blood returning from the lungs still continued to be of its bright red hue. At the same time that the respiration had diminished, the heart was beating with excessive rapidity. The phenomena that take place in the lungs are ecchymosis and effusion of blood; to show which M. Bernard brought forward the lungs of a dog, whose nerves had been cut the day before. They were hepatized, and the animal had been suffocated.

After this operation there are then *immediate* effects and *consecutive* effects.

What relation do these phenomena bear to each other? In the first moments succeeding the operation, as we have seen, there is no sensible change in the blood that has passed through the lungs; it enters black, and returns red, as it did before. Dupuytren, it is true, said that the blood was black in the arteries, but he made use of young animals, and in them, as has been said, there is a complete closure of the glottis, and no air can enter the lungs. The blood continues then changing as before, until the *consecutive* effects of the operation take place. The second or third day the lungs are anatomically changed from effusion and coagulation of blood, at first in small spots, but at last the whole organ is invaded, so that it is impossible for the air to come in contact with the blood. All this, however, is but a change taking place in the second period of the operation; it is a consecutive effect, and in every period the temperature of the body is diminished. This phenomenon, of the diminution of the animal heat, takes place *at once* after the division of the pneumogastric nerves, and if it were admitted that the caloric was generated in the lungs, it should have remained the same while the usual changes are taking place there, as they are shown to do until the second period of the operation, when the consecutive effects manifest themselves.

What is the cause of this decrease of the tem-

perature? In speaking of the liver, it was said that the blood was there warmed, and when you cut the par vagum in the cervical region, you cut also the nervous branches supplying that organ, and all the others supplied by it below the neck are paralyzed. This decrease depends on the cessation of the functions of the liver; all the modifications the blood undergoes there cease at once to be accomplished, and the returning blood, instead of having more caloric, has but the same. There is an action upon the lungs, but it is the action upon the liver that causes the diminution of temperature.

Direct experiment, the introduction of the thermometer and measurement of the temperature, shows that the blood is cooled in the lungs; and it has been most clearly shown, that the other facts brought forward to show that the blood is there heated, must be differently interpreted.

After the section of the pneumogastric, some peculiarities in the blood have been pointed out. It is said to have a greater tendency to coagulate. Coagulation is said to take place in the heart and obstruction of circulation to result. This taking place in the bloodvessels, was said to happen after death, but now it is known not to be so; for, kill the animal after twenty-four hours have elapsed since the operation, open the heart at once, and you find coagulated blood in its cavities. These clots can become the cause of very serious affections; for, although it might be supposed, that the coagulated

fibrine could remain and do but little harm, merely remaining an inert body, and not possessing any irritating properties, yet if a few morsels of fibrine be injected into the jugular vein, the animal dies with most acute inflammation of the lungs. M. Bernard only mentions this as a curious fact, that fibrine, which is not known to possess any irritating properties, produces intense inflammation when in the bloodvessels. It is not known if the blood of an animal after the division of these nerves becomes venomous. Magendie says it does; and he has likewise remarked that in the last stages of starvation there is a change in the blood, it becoming totally venomous, and producing immediately the accidents of putrid infection after its injection into the system of another animal. The influence of the lungs, then, upon the blood is not so great as has been said, but still it is very great, and it is impossible not to see that they produce great modifications therein. Chemical analysis is not, however, at the present day, able to give us an explanation of these modifications. This change of some carbonic acid and some oxygen is not sufficient to give a reason for them.

Independently of the chemical differences, there are some that are mechanical, connected with the circulation. The lung is an organ through which, in the higher animals, all the blood must pass, and in them there is a heart, whose special office it is to drive the blood into it. There is a system for

the lungs and another for the whole body, and their force is very different.

The right ventricle has much less thickness of walls than the left, and those of the pulmonary artery are also thinner than those of the aorta, as if manifesting a less degree of force on one side than the other. According to the calculations of M. Poiseuille the difference is as one is to eight. But it has not perhaps been well estimated in his experiments; and before the close of the course, M. Bernard said he would make some others, he had recently devised.

In experiments somewhat similar, it will be remembered that there were two forces to be observed, a pressure of the arteries, and an impulsion of the heart; but in these, as the ventricles are situated below the valves, the arterial pressure cannot exist. Unlike the arteries, the ventricles are either full or they are empty, so that the barometer being introduced, there is a change from zero to 140 millimetres.

At the commencement of this course, it was stated that many experiments showed the arterial pressure to be the same everywhere throughout the body. This, however, is not exact; it is not the same at unequal distances from the heart, and will be shown not to be so, by means of a newly invented instrument for measuring the force of the blood in the circulatory system.

His teaching, M. Bernard said, was not historical, but experimental; and therefore, it must not

be surprising to see him go back to what he had already taught, and show the errors, and the causes of those errors.

At the commencement of his course, it was said, that experiments had been made to determine the force of the blood's circulation, and their result was singular and in opposition to all ordinary hydraulics. This opposition was not sufficient, however, to show them to be false, for the laws of both physics and chemistry are often much modified in the economy.

The conclusion derived from the experiments was, that the blood circulated in the body, the heart being the organ of its impulsion; and, according to ordinary hydraulics, on account of friction, the force should be less in the extremities than near the heart. Yet, at variance with these laws, M. Poiseuille, making use of the instrument before described, was brought to the conclusion, that the force in all parts of the body was the same, so that friction, a cause of the loss of force, was not sensible in the bloodvessels of the living body.

M. Magendie agreed to the truth of this conclusion. He made some alteration in the instrument, constructing one having a reservoir of mercury attached to it, in order to render it more sensible to slight oscillations. He called his instrument a cardiometer, and it was useful in measuring the effect of nervous disturbances, &c. These conclusions were generally accepted in

science, and it was maintained that the force was the same in all parts, and in all animals, and amounted to a force capable of raising a column of mercury 150 millimetres. They were, however, denied by M. Volkmann, who asserted that the force went on gradually diminishing as you receded from the heart. There was, however, in these experiments, great possibility of being deceived. When this mass of mercury was put into motion, the oscillations came from very different causes. When the animal struggled, when he cried, there were changes, and they were forced to take a mean of all their observations. The highest and lowest points of twenty were taken, and then the mean was calculated; it was found to be 150 millimetres for all parts of the body. There were here great sources of error, for they did not act upon all the arteries at once, and the condition of the animal must have been different each time. In addition to the struggling and crying, they operated first on the carotid, and then after placing a ligature around that vessel, they proceeded to the crural, but when you tie one artery, the pressure in the others is increased. Add to these, the exhaustion of the animal, the loss of blood, &c., and you see how great and how numerous are the sources of error, all making their experiments deficient. The errors were not in the observers, but in the instruments, and they were forced to give the results they did.

M. Bernard has had therefore an instrument

constructed, that enables him to act at the same time on two arteries. It consists simply of a hollow tube of glass, bent in the centre so as to have two vertical and parallel branches. This is attached to a scale as usual, and the upper extremities of the parallel branches are bent at right angles over the top of the scale, for greater convenience of attachment to other tubes, and there furnished with stopcocks. Mercury being poured into the tube, of course it will remain at an equal height in both branches. This instrument is a double barometer, in place of a single one; it is differential, in place of being absolute. In others, the mercury is between the air and the blood, and two absolute observations are separately made, while in this, one opening being attached to one artery, and the other to a second, the mercury is between the two forces at the same moment. You make two arteries beat against each other. If the two pressures be equal, the equilibrium will continue, but if not, one column of mercury will ascend, and the other descend, just as when two animals meet, the stronger will make the more feeble recoil. When this instrument is connected with the two arteries you are desirous of comparing, if one be stronger than the other, it will push with more force against the mercury. There can be no cause of error here, for the two observations are simultaneous, and of course the action of causes influencing the pressure is the same on both arteries. M. Bernard had applied this in-

strument, and had obtained the following results. When he took the two carotids or the two crural arteries, the equilibrium in the two columns of mercury was perfect, showing that one pushes just as hard as the other. The mercury remained at zero on each side; there were oscillations of 1 or 2 millimetres, but only small jerkings, and on one or the other side indifferently. The pressure is then the same in the two arteries, right and left, at equal distances from the heart. This is the way it had been done: the upper part of the tubes being filled as usual with carbonate of soda, to prevent the coagulation of the blood, and connected with the two arteries, the two stopcocks were opened at the same instant, and the mercury remained the same; or one alone being opened, it mounted 150 millimetres higher on one side than the other, and descended again to an equilibrium on the opening of the second cock. By either proof the result was always the same.

If the arterial system were a *communicating* system, as has been believed, you should have the same pressure from both sides of a divided artery, the peripheric and the central. On experimenting with his instrument, however, M. Bernard had found a very great difference in the height of the two columns, and this difference must be the exact measure of the difference of pressure in the two ends. Every one knows the communication between the vertebral arteries and the carotids, and if this communication were a

closed one, the pressure in the two ends should have been found to be the same. There was, however, a difference of 38 to 44 millimetres in the height of the two columns, and therefore this cannot be a *closed* communication that exists between the arteries. The pressures had also been measured separately, by detaching alternately the tubes; in one case, they were, 160 and 122, and in another, 150 and 106 millimetres, showing, as before, a difference of 38 and 44. Had the communication in the arterial system been *closed*, of course the pressure in the central and the peripheric ends would have been the same.

The arteries in the different parts of the body, do they contain blood that is moved with an equal pressure? This is what has been asserted, and it is very easy to test its correctness with this new, differential instrument. The crural artery and the carotid had been connected by tubes to the two ends, for which purpose he had had constructed tubes of lead, of equal length, and filled with carbonate of soda. For greater convenience, other small tubes, about two inches in length, were previously introduced into the cut ends of the arteries, into which the leaden could be fitted when all was ready. Thus arranged, when the stopcocks were turned, the mercury would be pushed toward the feebler. The result was, that there was a difference in the columns of mercury of 30 millimetres, this indicating the excess of pressure in the carotid. This shows that there is really a

difference in the pressure, as the arteries are nearer or further from the heart, and it is then positively certain that the other conclusion, that the pressure is the same, is incorrect.

Another fact was observed that is very curious. It was found that in the different arteries, the difference in pressure between the two divided ends was not the same. In the carotid, as has been said, it was from 38 to 44 millimetres; when the two ends of the crural were examined, it was 30 millimetres. This is singular, for it is just the same as the difference of pressure between the carotid and the crural.

The pressure, then, is more feeble in the peripheric than in the central end, but the difference seems to become less as you recede from the heart, being in relation to the amount of pressure in the vessel. This must be submitted to new experiments, but it is very interesting, as it may show what purpose the multiplication of the anastomoses serves, as you remove from the heart.

By means of this instrument, in place of taking two animals separately, and afterwards comparing the results of your observations, you can take the two together, and make the two hearts beat against each other, the difference in the forces marking itself at once upon the scale.

This instrument is again very important at the present time, for M. Bernard is making some experiments upon the influence of the nerves upon the capillary circulation, and he can now apply it

so as to measure the force on both sides of the body at the same moment. He said that he had applied it to the two facial arteries at the same level, and when measured, the mercury was in equilibrium. After cutting the sympathetic, a change was seen, and in the three cases in which he had already applied it, he had found a very great augmentation of pressure on the side of the face where the nerve had been divided. Now with the other instruments you would not dare to trust to such results, for the causes of error are too great.

At the next lecture, M. Bernard made the application of his differential instrument before the class. A dog being held with his back upon the table, the crural artery was sought, and a ligature applied; the same was done on the opposite side, and also in the two carotids. The two carotids were of the same size, and he said he would return to the question, if the volume of the artery makes a difference. The instrument was applied to both the crurals, and the stopcocks turned. The mercury slightly oscillated, but at the same level in both columns. When one cock was closed, there was at once a break in the equilibrium; a very great difference was seen. The force with which the blood was moved was 220 millimetres. One of the tubes being then removed and united to the carotid artery, while the other was left in the crural, there was a difference in the columns of 60 millimetres, one side having gone down 30 below

zero, and the other, to which the crural was attached, having been pushed up 30.

The explanation of this difference, in this case amounting to 60 millimetres, must be sought for, and it can only be accounted for by the loss resulting from friction. Other experiments show that this loss always goes on increasing as you leave the heart. In a horse, he had found the difference between the carotid and the nasal artery to be 60 millimetres also, and he intends to make other experiments, in order to find out the relation existing between this loss and the distance.

Another fact stated in his last lecture, but which M. Bernard did not show to the class in this, from want of time, is very interesting in a surgical point of view. It is this : that a tube being placed in the peripheric extremity of a divided artery, and another in the central, a difference is found to exist, which in the experiments he has made amounts generally to 40 millimetres. This pressure in the peripheric extremity is caused by the blood returning; and how does it come back? When a ligature is placed upon an artery in order to cure an aneurism, it is said to be done because the impulse of the heart is constantly distending the artery, and causing it to enlarge, and in order to put an end to this impulse, it is necessary to tie between the heart and the sac.

This supposes that the pulsations do not come from the distal end, and in some cases they have nevertheless been found to do so. This persistence, or this return of the pulsations in such cases, leads

us to the examination of the anastomoses in the arterial circulation, for it can depend only upon them.

The two carotids ascend the neck, and in the head anastomose very freely, and, as is always the case, the more freely, the further they get from the heart. The same is true of the vertebral arteries; and the great anastomoses these four arteries form at the base of the brain are well known to every one. When you tie a carotid, you prevent, it is true, the blood from arriving from the heart, but you do not prevent the blood from entering by these anastomoses. This force, from the anastomoses, is not so great as the other; as was said above, there is a difference of 40 millimetres. The pulsations are also more feeble, but they do exist, and can be seen perfectly well. Hence, when an aneurism is operated upon here by a ligature, between the sac and the heart, you should still have pulsations, though much diminished in force. In all arteries this is not the case.

M. Bernard has not as yet made the experiment, but he thinks that very probably, after some time has elapsed, the force at the peripheric end becomes greater from enlargement of the anastomotic branches.

He also said he intended to take an animal, and laying bare and dividing the crural artery, as he had just done, to note the difference in the two ends; this done, he would amputate the limb, only leaving the vein and artery, and all anastomotic

branches having been thus evidently cut off, he would see if all peripheric pressure had not ceased, as he anticipates.

The arterial system must not be considered as *closed*, as forming a closed system with the venous. The capillary system is a true barrier, the blood having once passed it, cannot return and influence the pressure of the peripheric end. The arterial system can be considered as an open system, as one that empties into another, and hence it is not extraordinary to see the phenomena we have just observed.

The capillary system can be considered as a valve that does not prevent the blood from leaving, but from coming back.

It was formerly said not only that the arterial pressure was about the same everywhere, but also that it was not much affected by the quantity of blood in the animal. Magendie made the carotid artery of one dog empty into the jugular vein of another, but did not find much difference. M. Bernard said he would repeat, these experiments, and would see if they were not capable of correction. When an animal eats and fills the abdomen, this should tend to push more blood into the general circulation, as when in dropsy the vessels of the abdomen are emptied by the pressure of the water. In dropsy, if you empty quickly the abdomen of its water, the blood returns into those vessels, and syncope can occur from the sudden diminution of the pressure in the

general circulatory system. All these differences the old instruments were unable to appreciate. The veins must also be studied, the abdominal as well as the others, and also the right and left ventricles. He promised to make a number of experiments on these subjects before the next lecture, when it would be seen how far the differential instrument was serviceable in these investigations.

We can say that the force of impulsion is from the left ventricle, and that it goes on diminishing to the right, and it may thus be stated in numbers: 20 at the heart, 15 in the aorta, 10 in its divisions, 5 in the veins, and 0 at the right ventricle. The force from pressure is much greater in the arteries than in the veins, for there is an abrupt decrease in the capillaries from their tenuity and ramifications. The force from pressure being then zero in the large venous trunks, and the impulse of the heart being extinguished, another force is requisite, and this force comes from the respiration. Various causes can intervene, so as not to allow the diminution of the pressure in the arterial system to be so very gradual as was just stated. When the system is very full, the differences are more difficult to seize; when emptier they are much more apparent. Again, the arterial system tends constantly to empty itself, receiving from the heart, and losing by the capillaries. Suppose a difficulty to occur to the emptying, from the efforts of the animal

hindering the venous circulation; this would cause a difference of pressure, because it would be increased on account of the elasticity of the arteries being more exercised.

It is well known, that, when an animal dies, the arteries are found empty. When they are not so, it is in those cases in which the respiration does not cease before the heart, for if its beating continues when no more blood is arriving from the lungs, all will pass into the veins. M. Bernard has made observations on the two kinds of death, the one so common that the ancients, finding the arteries always empty, thought they did not carry blood. But in some cases, the two organs die together, as in poisoning by strychnia, and you then find both systems full of blood, for there is an arrest of the heart and of the lungs at about the same instant. From this, the continuance of the beatings of the heart longer than the respiration in the immense majority of deaths, has arisen a difficulty in calculating the power of the ventricles. The right one, being distended, looks much larger; while the left, being contracted, looks smaller. To judge properly, a heart should be taken from an animal that has died under such circumstances that both systems are full of blood, as, for example, by the administration of strychnia.

The right, or venous, system can never empty itself into the left, or arterial. It has been said that it might, because you can make an injection pass from one to the other when the animal is

dead. When, however, an animal is *just dead*, it is impossible to force an injection from the veins into the arteries, it is prevented from passing by the capillaries; and during life it is this system that prevents the return of the blood. It might be objected to this that some time after death, when the action of the capillaries is extinguished, the blood does not flow back, but this is owing to the coagulation that takes place in these vessels and obstructs them.

M. Bernard made the following experiment, wishing to show by the administration of a certain poison, the curara, in which the respiration ceases long before action of the heart, that, the circulation going on, the pressure in the arteries diminishes with the diminution in the respiration, until it descends to zero. He made use of some from a new flask, which had not before been opened, and putting some under the skin of the thigh, deposited a few drops of water upon it, in order to assist its solution. The pulsations of the heart became more and more feeble, but when there was no pressure at all in the arterial system, when it was entirely empty of blood, you could still hear the beatings of the heart. It is true that Haller has sustained a contrary opinion, and it may be the right ventricle only that continues to beat.

This poison was not in its action like the curara usually is; it was much more slow. The animal had convulsive movements, and during them the

pressure in the arteries was very much increased, for they prevent the passage of the blood into the capillaries. There is here a tonicity of the capillaries, as after strychnine. M. Bernard said he had seen many animals die after the curara, without their presenting any convulsive movements; in fact, he had *never* seen any follow its administration. There may have been some peculiarity in that contained in the new flask.

Legallois observed, long ago, that the destruction of the spinal cord, in the dorsal region, prevented the contractions of the heart; after this section of the cord in the inferior part of the neck, the animal does not die at once, for he breathes by the phrenic nerves. The instrument being attached to the carotid, after the section of the cord, there is an instantaneous diminution of pressure, and at last it is zero. When, however, the animal seems dead, the heart recommences to beat, and this is just at the moment when the sphincters relax, the pupils dilate, &c., &c. M. Bernard said he was about to make other experiments to study the changes of pressure at the time, when in death, the two phenomena, circulation and respiration, were being extinguished.

To finish the study of the blood, the influence of the nerves remains to be studied.

The blood has been examined chemically again and again, but as we have seen, there is yet much to do; we do not know the reasons of the modifications it undergoes. In the liver, some

proximate principles disappear and others are formed, sugar being formed from nitrogenized bodies: chemistry has never yet been able to do this. Thus then the profound chemical modifications that take place under the influence of life, we cannot repeat in the laboratory. Relatively to the movement of the blood, we have seen that it has been much experimented upon, and from what M. Bernard has shown, the laws of dynamics can be applied to explain it.

It remains, therefore, to examine the influence of the nervous system, for it is evident that, if there be any difference between what passes within the body and that which occurs without, that it must be attributed to this. This influence, on the chemical phenomena, is enormous; we have seen that the effect of dividing the nerve supplying the liver is to destroy the production of sugar, the chemical modification ceasing at once to take place. The elements of the liver cannot act without the stimulation of the nerves; and you can, moreover, by exciting them, augment the production of sugar; the function becomes exaggerated.

But the influence of the nervous system is not confined to one organ; it extends to all the parts of the circulatory system, and only escapes us because chemistry has not yet been able to detect the modifications it causes. Before knowing that sugar was formed in the liver, it was impossible to show this influence there.

M. Bernard will give in this, his last lecture,

some results of experiments made in order to study these modifications in other parts of the body, and to determine the influences of the nervous system on the composition of the blood. He has sought to study them on the periphery of the body, by means of the section of the sympathetic nerve.

It has already been stated, that when it is divided, the *apparent* phenomena change; and he brought forward a rabbit to show that on the side of the section there was a considerable difference of temperature, the heat of the parts there being very much increased. Now, the question is, to show what these phenomena are that take place in the part; and, moreover, if these modifications are only mechanical, or if they are chemical. They are very long and very difficult to study; M. Bernard had been engaged in them for several months, and his conclusion is, that these modifications are not mechanical only, but are really chemical. He had chosen horses for these experiments purely and simply because the vessels are larger; in the rabbit they are too small for the purpose. In a horse, the *apparent* phenomena are the same as have been seen in the rabbit,—greater activity of the circulation, and elevation of the temperature; in fact, they are seen in all animals. And what are the phenomena in a *chemical* point of view? A considerable modification in the coagulation of the blood has always been remarked. By a singular privilege, the blood of the

horse coagulates more slowly than that of other warm-blooded animals, and it would seem as if the globules had greater density, so that when you bleed a horse, you see the globules descend, and have a white coat, a buffy coat, whether he be digesting or not. But after the division of the sympathetic nerve the buffy coat diminishes in size, and at the end of half an hour, the blood drawn does not present any at all; the blood is like that of other animals. The cause of this change is evidently the greater rapidity of the coagulation. While before the division of the nerve it took place very tardily, it takes place afterwards almost at once. It must have been the cutting of the nerve that caused this; and this is, moreover, shown by the fact, that the blood from the other side, where the nerve is intact, remains as before; the effect is local. The effect continues local about an hour, but at the end of a certain time it becomes general, and the blood of the whole body is affected.

The venous blood becomes much more red than it was before; it is almost as much so as that in the arteries. The red blood from the arteries becomes black on exposure to the air, by the formation of carbonic acid at the expense of the oxygen; but this red blood becomes dark almost immediately; the one becomes so after the lapse of 18 or 24 hours, but this at the expiration of an hour.

The heat of the part is greater, and this has been

said to be but a mechanical phenomenon, because supposing that the sympathetic nerve gives contractility to the capillary vessels, when it is cut they must dilate. It is only a pure and simple paralysis of these vessels, it is said, which allows a greater quantity of blood to enter, and as a consequence the part must be warmer. But, if this be so, how can we understand that the coagulation is so much more rapid; if it were but a simple paralysis, this could not be. The truth is, there is another blood there, a modified blood, and there is not only a preservation of the heat, but an augmentation of it. The thermometer shows that the heat is greater on one side than on the other, and it might be said that this is very simple; that it is because there is more blood there, a large mass cooling less rapidly than a small one. This could explain a difference of $\frac{1}{2}°$ or $\frac{1}{3}°$, but there is a difference of 6° or 8°, Centigrade. And this is not all; in ordinary circumstances there is a cooling of the blood at the periphery, but there is, in these cases, more heat in the blood returning than in that going. It is consequently impossible to account for the difference by a pure and simple dilatation of the arteries.

How, under the influence of the sympathetic nerve, this change occurs, M. Bernard said he did not know, but it was most surely not only from mechanical, but from chemical modifications in the blood.

In regard to the influence of this section, on

the force of the circulation, he has made many experiments, but they must be repeated many times again. Their results have *always* shown an augmentation of pressure on the cut side. If it were but a simple dilatation of the arteries, from their paralysis, this would not be found. He used the differential instrument, applying the tubes to the right and left facial arteries, having made the section between the upper and lower cervical ganglions of the great sympathetic.

This differential instrument only measures the pressure; it does not give the force of impulse of the heart, for the pulsations act on both sides. This force can be measured, however, by the simple barometer, and it is seen to be greater in the side supplied by the divided nerve. How can this be explained. These impulses come from the heart, and how can it be supposed that those in the one carotid should be greater than those in the other. The instrument, applied in the two carotids, shows the equilibrium to be perfect in them, at the time of the pulsations. The difference is higher up, and must be owing to a change in the activity of the capillary circulation.

These are the phenomena that are witnessed, and they are exceedingly difficult to study. They are very similar to those that take place in inflammation; at least, they resemble them to a certain extent. When a part is pricked, you see all around the point a greater quantity of blood, and an increase of heat. This influence of the

nerves on other parts, on other organs, must be examined. It is very difficult to study the blood chemically; it is very difficult to account for the changes, and, above all, the slight changes that take place. Physiology serves as an intermedium between physics, and chemistry, and pathology.

It is just here, in the influence of the nervous system, studied *step by step*, on the blood, that much remains to be done.

In this course, M. Bernard said, in conclusion, although he has given the present state of the science, he has not been able to give an explanation of these phenomena.

APPENDIX.

Note A.

In his Course of Lectures on Normal and Pathological General Anatomy, delivered in the winter of 1853–4, M. Robin gave an account of the blood-globules, which differs in some particulars from what is said of them by M. Bernard.

In points connected with microscopy, M. Robin is most probably more correct, and therefore the following extracts from notes taken at that time are here inserted.

The *red globules* of the blood are bodies, perfectly circular, and flattened, of a diameter, in general, of 0·007 millimetres; some, in small number, have 0·008, others, only 0·006; their thickness is from 0·002 to 0·003. These measurements are taken from the most normal blood; the abnormal will be spoken of hereafter. They are thinner in the centre than on the edges, being therefore *bi-concave.* This form has caused the belief of the existence of a nucleus, from the bad interpretation of a physical phenomenon, for the

angle of convergence of the rays of light must be different as the lens is raised or depressed, and the globules will thus present a centre at one time clear, at another dark, from the refraction of the light. When seen by reflected light, they are red, when by transmitted, they are yellowish, the difference under the microscope being very striking.

Chemical agents have the following effects upon them. When in contact with water, they swell and become spherical, and at the same time the water separates them from their coloring matter. Water does not dissolve them unless the action be prolonged for several hours, and the proportion of water be very great, 50 or 60 times more.

Acetic acid dissolves them very quickly, and sulphuric acid still more so. Muriatic acid and nitric acid do not dissolve them,—they cause the formation of excavations. Potash and soda, when much diluted by water, dissolve them more quickly than water alone; by themselves, they act as muriatic acid, causing excavations.

When the blood is morbid, there is a difference in these reactions.

Their structure is very simple, and M. Robin did not give a history of the different opinions about it, for they are too numerous. There is no *vesicle*—it is formed of globulin, half-solid, containing more carbon and oxygen than albumen, perfectly homogeneous, and in this *mass*, where there is a certain quantity of water, and of salts (phosphates, &c.), there is hematin, imbibing

equally every part. There is also a small quantity of fat; in some birds very small drops of fat are seen, and also in the human fœtus.

The globules of the fœtus are said to have nuclei, but this is incorrect; they never have any.*

While they are still in the bloodvessels, no morbid changes are ever seen. No deformed, or at all modified globules are ever seen in the vessels. In the last moments of cholera and of putrid infection, they become what is called *diffluent;* they become deformed much quicker when placed under the microscope, after extraction from the body.

In urine, the greater part of the globules remain intact, some become dentate on the edges, and others even *framboisés*, that is to say, not only irregular on the edges, but all over their whole surface. These alterations occur, above all, upon the addition of an acid liquid, as can be seen at any time, by pricking the finger, and adding some of the perspiration. When mucus is added, as that of the bronchial tubes in cases of hemoptysis, they remain entirely intact.

When they are effused in a cyst, &c., they are found in a series, in a pile, and this property is perfectly preserved in blood drawn from a man, for several days. The cause of it is much discussed; when out of the vessels, either after bleeding, or effused in the tissues, a viscous matter is seen oozing from their surface, as on flax-seeds in water, and they thus not only attach

* As will be seen further on, M. Robin has changed his opinion on this point.

themselves to each other by their surfaces, but also by their borders.

In apoplexies in the brain, in the liver, &c., several phenomena are observed. The globules are again absorbed, more quickly in the brain than elsewhere; a month is a short time for this to be accomplished. After the globulin has separated from the hematin, the latter becomes crystallizable, in rhomboidal bases; much of it thus forms crystals, and much also remains an amorphous mass. Another peculiarity is, that when blood remains long without being absorbed, as in cysts of the ovaries, of the thyroid gland, &c., you find a brownish liquid, and there you find the globules, but altered, and their alteration can be divided into three principal degrees. In the first, the globules pass into a particular condition, seen also, when blood is allowed to putrefy out of the body; they become smaller (0·005 millimetres), also darker. In the second degree, there is a separation of the parts, the globule continues to be sprinkled by some hematin left, which has the same color, but is only on the periphery arranged in dots. In the third degree, the globules are altogether colorless, and this is only seen when the cyst is very small. The action of chemical agents on these last is this,—water has no action upon them, acetic acid acts, but the rapidity of its action is not so great as upon the normal globule. In some very small cysts of the conjunctiva, or of the large ligaments, &c., you see alongside of them, others very white or grayish, composed of blood-globules en-

tirely discolored; the hematin, the first absorbed, has been taken, and the globulin left.

In the embryo, the red corpuscles appear when there are no more embryonic cells, when only a very few of the embryonic cells are left in the thickness of the tissues. They are born *at once perfected* (*de toutes pièces*), in the serum of the heart, for it contains serum before it contains red globules; they do not come from the embryonic cells. We know at the present day that they do not come from the white globules. They are formed *de toutes pièces*, just as you find epithelial cells to come on a blistered surface.

Bleed an animal as far as possible, then feed him well, and from hour to hour examine the blood; you will see the globules return. At the moment of making their appearance in the embryo, they are less colored than in the adult, and they are less flattened.

The *white globules* are bodies very important to know well. They are bodies of a completely spherical form, and of variable volume, which is always greater than that of the red; in the normal blood of the adult they are generally 0·008 millimetres in diameter. They contain granulations, and are completely deprived of nuclei.

Water causes the granulations to assemble together, and swells the globules a little, rendering them somewhat more transparent. The first action of acetic acid is to assemble these granulations together into a single mass, which soon de-

taches from the rest; this mass takes a reddish tint. This action takes place in eight or ten minutes. There is nothing interesting in the other reactions.

With respect to their structure they are divided into two varieties. The first, that of the adult, which has just been described, is a homogeneous mass sprinkled uniformly with granulations of a large size.

The second variety is only found, normally, in the fœtus and young children, in greater proportion the younger the embryo, and always mingled with the other variety. In adults they are also found in chronic diseases of the liver and spleen. Their volume is 0·008 to 0·015, and they are above all characterized by holding a nucleus in the centre, which is nearly spherical and very visible; in some, but very rarely, there are two. The action of water is the same as upon the other variety. Acetic acid swells the mass, dissolves the granulations, and leaves the nucleus, coloring it a winey-red.

The quantity of white globules, compared to the others, in the blood of the fœtus is normally from 5 to 10 per cent.; of the adult in good health, it is from 0·5 to 1 per cent. Of course these quantities are approximative. Again, when in defibrinated blood the globules are deposited, the red being the heavier, the white are found above, and their proportion can thus be measured.

While circulating in the vessels, they are always

applied against the internal surface of capillaries, as can easily be seen in the young mouse, or in the frog, &c. They are not uniformly distributed in the economy, some blood containing more than another. There are more on the internal surface of the capillaries of the glands than elsewhere; also more in the capillaries of the brain than in those of muscles and of the skin.

There are some chronic diseases of the liver and of the spleen where the proportion can be 15, 20, even 30 per cent. And in such cases you always find developed amongst them, those with a nucleus.*

* This disease was first described by Bennett, and he published his first case as one of pus-globules found in the blood, mistaking this variety of the white globules, the large with a nucleus, for pus. As the distinction between them presents some difficulties, it may not be amiss to give here the means employed by M. Robin.

The white globules of the adult, with no nucleus, are easily distinguished by the smallness of their size, being only about half as large (the pus globule has a diameter of 0·010 to 0·016 millimetres), by the absence of nuclei, and by the effect of acetic acid on the granulations, for those of pus are dissolved.

From the pyoid globules, a variety of pus globules, the same with the other, with the exception of its containing no nuclei, it is still more easily distinguished, for acetic acid renders these entirely transparent. If any fat exist, it is easily recognized. The white globule of the blood, which contains one or two nuclei, can be known from the pus-globule by means of the nucleus. In the former it is granular, and has a diameter of 0·005 to 0·006 millimetres, while in the latter, it is rarely granular, and has a diameter of but ·002 to ·003. Moreover, acetic acid makes the nucleus reddish. Of course this variety of the white globule containing a nucleus, could not be confounded with the pyoid globule.

When the white globules of the blood are placed in serum, a peculiar phenomenon is witnessed, that is met with in many kinds of cells in lower animals, oysters, &c. Expansions are seen on the periphery of the cells, and these expansions elongate and shorten. The white globules are the only anatomical elements of man, and of mammiferous animals, that show this.

The periphery of the cell previously becomes irregular, and these expansions are transparent and sometimes finely granular. The white globules of insects and of all animals present this phenomenon. In man it commences ten minutes after the blood is drawn, and ceases at the end of five or six hours, and when it ceases they become again spherical. In the dead body all are spherical.

Normally, in the lymphatics, a small number of white globules exist, more in herbivorous than in carnivorous animals. In the lymphatics of the neck and of the testicle, there are more than in the chyliferous vessels.

Globulins are anatomical elements of an entirely spheroidal form; their diameter is 0·005 and does not vary. There are many of them in the lymph and the chyle, and they are more abundant in the fœtus, than the adult. They have scarcely any color, being slightly grayish. They enclose some five or six granulations.

With water there is no reaction, acetic acid

does not dissolve, but makes them a little more transparent.

Their structure is, a homogeneous mass sprinkled with a few granulations. No physiological or pathological peculiarity is known to be connected with them. They are never known to increase or diminish in quantity, except in Leucocythemia, when they are somewhat increased.

In a letter received from M. Robin since the commencement of the publication of this book he says:—

"Since your departure, I have had the opportunity of obtaining four human embryos, perfectly fresh; their lengths were 3 millimetres, 8 millimetres, 16 millimetres, and 25 millimetres. I made some interesting observations upon them, relative to all their tissues, and particularly to their blood. I send you, here, the *résumé*, which you can translate and publish, if you think proper.

"The majority of the *red globules* of the blood of embryos are from 8 to 12 millièmes of a millimetre broad, and some of them are even 13 and 14 millièmes. The most of them also have one, or rarely, two nuclei. These nuclei are spherical, finely granular, from 3 to 4 millièmes of a millimetre broad; but the globules of the blood are *bi-concave* as the globules of the adult. In embryos, 25 millimetres long, already *not more than one half* of the globules have a nucleus, the others have no nucleus, and are of about the same size as the globules of the adult, that is to say 8 millièmes of a

millimetre. The nucleus is rarely in the centre of the globule, but almost always a little to the side of the *central concavity* of each face, and they do not prevent the globule from having the flattened form of the globules of the adult. These globules fold upon themselves, or become dentated; with the greatest facility, as soon as the serum is a little changed. At the same time many among them take an *ovoid* form, but not at all an *oval-flattened;* a fact which easily distinguishes them from those of fish and of reptiles, which are *oval and flattened.* This form, which Mr. Vance told me he had seen with a professor of Vienna, does really exist, but it is an accidental deformity, taking place with facility from alterations in the serum, in the same way as the foldings and other irregularities of which I have spoken.

"The globules of the embryo, seen in a serum unchanged or but slightly modified, are elastic, and resume with rapidity their form when, having been deformed by compression, they cease to be compressed. They often assume a very elegant form, when they are accumulated and reciprocally compressed.

"The nuclei of the red globules are unaffected by acetic acid and water, but the mass of the globule is affected as that of the globule of the adult.

"I was able to verify with ease, on these embryos, that the red globules are in no way derived from the white globules, which act very differently, have another structure, &c.

"In embryos from 40 to 50 centimetres (millimetres ?) long, the globules have already the volume, which they will always have, and no longer have nuclei. The *ovoid* form of which I have spoken above is generally less regular than those I have represented."

Accompanying the letter was a small drawing, giving the appearance of the globules under twenty-two different forms. On this occasion, as on many others, in the course of this work, I regret not to be able to offer representations of what is described in the text, but in minute microscopical investigations unless the plates are most correctly executed, they are of little value.*

* In his letter, M. Robin says, "You will much oblige us by praying your compatriots to send to the Society of Biology, or to us (himself and M. Bernard) one or several copies of their publications, in order that we may be *au courant* of American Science, with which our relations are too limited, and we would much desire to see them multiplied. You can have them addressed by the post, prepaid, to M. Rayer, membre de l'Institut, No. 14, Rue de Londres; or to me, No. 17, Rue Hautefeuille, either by M. Baillière of New York, or by the correspondents of the house, Hector Bossange et fils, libraires, 25, Quai Voltaire, Paris."

Note B.

A more extended account of the anatomy of the vessels concerned in the circulation may be both interesting and useful.

The vessels are the capillaries, the arteries, and the veins.

The capillaries are tubes, of three varieties, which differ in structure and in diameter, but as they are continuous, have an insensible transition into each other.

The first variety has but one membrane, and a diameter of from 0·007 to 0·030 millimetres.

The second has two tunics, perfectly distinct, and a diameter of 0·030 to 0·075 millimetres.

The third variety has a diameter of from 0·75 to 1·50 millimetres, when they become visible to the naked eye. They can be distinguished as venules and arterioles. When smaller than 0·010 they cannot be distinguished as one or the other, and have a peculiar structure, neither venous nor arterial.

The capillaries of the first variety are hyaline, transparent, and contain no striæ, nor fissures, nor granulations, in the normal condition, though when morbid they present some modifications, above all deposits of fatty granulations. Acetic acid renders them somewhat more transparent, but does not dissolve them. The thickness of their walls is 0·001, and 0·005 remains for the open-

ing, which is smaller than the globules of the blood, and they are therefore forced to lengthen themselves a little in order to pass through. This wall is homogeneous and contains no perforations, so that there can be no hemorrhage without rupture of the vessels. Hemorrhages by exudation are creations of the fancy, and are not at all founded upon observation; in scurvy, in the menses, in purpura, there is always a rupture of the vessels, and upon examination you can always find them broken.

In the wall are long nuclei, with generally no nucleolus, their length in the direction of the vessel, and projecting, sometimes outwards, sometimes inwards. They are oval, and longitudinal, with a length generally 0·005. In the brain are spherical nuclei, without our being able to say why.

The second variety are tubes, which offer the membrane with longitudinal nuclei, and a second envelope with transverse nuclei, whose direction is completely perpendicular to that of the others. The appearance is very characteristic; when they are seen at the side of the vessels they appear round, just as an egg when viewed from the end. This, and their volume, are what distinguish this variety from the others. Acetic acid has the same action; it does not dissolve, but renders more transparent.

In the third variety, a third tunic of cellular tissue is added, the other two tunics being just the same. The fibres of this cellular tissue are almost

all longitudinal and parallel. There are some elastic fibres, but they are very rare.

The third tunic exists in the capillaries of the brain, and when it is said that there is no cellular tissue in the brain, it must mean, around the nervous tubes. In this variety you commence to see two parallel vessels, one a vein, the other an artery; they are no longer in meshes, in a network, anastomosing with each other. In the vein the diameter is greater, and the nuclei are more closely together; you see this by dissolving the coat of cellular tissue by acetic acid.

The alterations of the capillaries will be described after the arteries and veins.

The *arteries* have three tunics; some anatomists give them six. Bichat, as every one knows, said they had three tunics, and he is very exact. Each of these three tunics has a different structure: they contain six kinds of anatomical *elements*, but the study of the *tissues* must be separated from that of the *elements*.

The first tunic is called the tunic of Bichat; he thought it only existed where the blood is red, but he was mistaken, it exists also in the veins, only it is much thinner. It is the internal coat, called *serous*, but it has not at all the same structure as the serous tissues.

It is a homogeneous substance, with longitudinal striæ, very fine, like fibrine, but not soluble in acetic acid as fibrine is, and as also the serous tissues are. Its thickness is about 0·10 of a milli-

metre. It has no vessels either in the arteries or in the veins, and it takes no part in atheromatous and calcareous concretions.

The second tunic is the thickest and the most complex; it is called the yellow elastic tunic; it is formed of elastic tissue, and in all vessels smaller than the aorta, of organic muscular fibres, which are principally towards the internal surface of the tube.

It contains no bloodvessels, absolutely none, so that if there be arteritis it is not in this tunic. There are none in the horse, where it may have a thickness of one centimetre.

This elastic tissue presents everywhere the same composition; sometimes the third variety of elastic fibres are found, and in some cases, here and there it is in the condition of layers. These elastic fibres then are found imbedded in, mixed up with, a substance of exactly the same kind, forming what is called the *substance fenêtré*.* This is not a tunic, as Henle says; it is only the elastic tissue, the same substance, in the form of a membrane in place of being in fibres. This *substance fenêtré* is also found in the fascia lata, and in the larger veins. When these fibres do not form a membrane, they are

* The third variety of elastic fibres of M. Robin, is one only met with in the arteries; they are more narrow and more frequently anastomosed than the others, and with edges a little irregular, dentated. The other two varieties are, those called also the dartoid, found everywhere where there is cellular tissue, and secondly, those forming the yellow elastic tissue, properly so called.

neither oblique nor longitudinal; they are anastomosed, in every sense. It is more easy to tear this tunic circularly than longitudinally, because the meshes formed by the anastomosis of the fibres have their long diameter perpendicular to the axis of the vessel.

The third tunic is the cellular tunic, in which are found, first, the cellular fibres ; secondly, the dartoid variety of elastic fibres, in about equal quantity with the cellular; and thirdly, the vessels, the vasa vasorum. The cellular fibres are crossed in all directions, and they give to the arteries their power of resistance.

The epithelium has been described as forming a tunic in the arteries, but it is only a continuous layer during intra-uterine life. It is the pavement epithelium and forms only one layer. After birth it is wanting here and there, and requires to be searched for. The vessels below one millimetre in diameter never have any. The same thing is true of the veins. In the umbilical arteries are a great abundance of organic muscular fibres, also in the ductus venosus, and in the ductus arteriosus. They can be taken in these places for a type.

There are some alterations peculiar to the capillaries and to the arteries.

In old persons, the capillaries, of every variety, undergo a senile change. It is characterized by the deposit of fat in the walls, always in a state of granulations. These deposits are very often larger than the wall is thick, occupying its whole thickness, and projecting; sometimes these are closely

connected, forming groups more or less considerable. Sometimes it is found in old men who are in excellent health, but it is chiefly met with in great abundance in persons who have died of apoplexy.

It can then be considered a lesion, determining apoplexy. It is a natural senile alteration of the capillaries, that is met with also in animals, and it diminishes their resistance, as can be verified under the microscope. It is found in all organs, and where the neighboring tissues do not give these vessels support, there will be bursting and consequent hemorrhage. This is why apoplexy is more frequent in one tissue than another ; and in the brain, where the tissue is the least resistant of the economy, the capillaries burst more easily than elsewhere. Hence, apoplexy is the most natural, the most frequent cause of death. In some individuals the alteration takes place sooner than in others. In most tumors the change happens sooner than in other parts. It is seen in most tumors, epidermic and cancerous, and in hypertrophies of the glands, and it is in the softest portions of these tumors, where the vessels are least sustained, that the hemorrhage takes place.

In the arteries, every one has often seen whitish or yellowish spots upon their internal surface. They are composed of fatty granulations, which have the same reactions as those in the capillaries, and they diminish the elasticity of the arteries, and also their resistance. These spots are formed of

fatty granulations in the yellow elastic tissue, and as they augment, this tissue takes another aspect; it becomes more homogeneous, and the fibrous aspect disappears. These granulations accumulate and form series, single or double, or a triangular mass. These masses are chiefly composed of cholesterine; there is also a certain quantity of oleine and stearine.

This is the first phase of a change that can have three.

The second phase of the atheromatous alterations is characterized by yellow, hard masses, of a homogeneous cut, and of a certain resistance; under the microscope you find the same granulations, and there is no interval between them, the whole mass is composed of them; and at times, you also already find some crystals of cholesterine.

In the third phase, you see a substance, grayish, soft, somewhat resembling honey, and of a micaceous aspect. This sometimes half liquid, grayish matter, presents but few granulations, it becomes almost diffluent, and in place of the granulations, you find crystals and also some amorphous matter.

This alteration is found only in the middle coat, and is separated from the interior by the tunic of Bichat. Sometimes this tunic is ruptured, and the masses present themselves in the interior of the vessel.

In treatises on this subject, calcareous depositions are given as the last phase of this alteration, but they have a march altogether different. The two

alterations often coincide, they are frequently found together, but it is more common to find the one, in its different phases. The other alteration is from the deposit of the phosphate and carbonate of lime.

In all treatises capillaries are said to be found in the arteries, but there are none. The arteries *nourish themselves*, but less well than parts possessing vessels, and it is on this account that they alter more easily than the other tissues, and are more difficult to act upon when thus changed.

Tissues that are not vascular, nourish themselves as others, only less well, and their lesions are very common. Lesions of the cartilages are also very often met with. The most ordinary cause of natural death is a lesion of one of the tissues thus nourished.

There can be no arteritis, properly speaking, for the arteries are not vascular. There can be changes of the cellular coat from inflammation, and then of the middle in consequence of them.

With the endocardium, however, it is very different. It has the tunic of Bichat, and, secondly, a tunic of elastic fibres, very numerous, but it is combined with cellular tissue, holding in it a good number of vessels. This is a tunic peculiar to the heart. This cellular tissue is quite abundant, and can be followed into the heart, interposed to the fleshy bundles. The third tissue of the heart, its *tunica adscititia*, is formed of the muscular fibres. This is spoken of in order to show that the struc-

ture of the heart and that of the vessels cannot be compared, the tunic of Bichat is the only one common to both.*

The walls of the veins are formed of four membranes.

First, the internal tunic, of Bichat, much more thin than that of the arteries, or of the heart.

The second has *longitudinal* fibres; it is vascular, and the thinnest of all, after that of Bichat. It is composed of cellular tissue, with its fibres *all longitudinal*, and of elastic fibres of the dartoid variety; the fibres are longitudinal, very vascular, and the meshes are also longitudinal. These elastic fibres are more abundant in the deep than in the superficial veins; they are very abundant in the pulmonary. They are never circular, being always longitudinal. These two tunics are the only two found in the sinuses of the cranium, and of the other bones.

In the other regions you find a third tunic, thicker than the others, and with *circular* fibres.

* It may be well to say a word as to the muscular portion of the heart. The fasciculi of the heart are marked by all authors as the same as those of animal life, but the striæ are one half finer, and the fasciculi are only one half as large, being from 0·030 to 0·080. There is an analogy as to the existence of striæ, but they are smaller, and between the fasciculi are a great quantity of molecular granulations. These granulations are normal, though they can be more or less abundant in different cases. The fasciculi are ramified, not extended from one part to another, and the branches are not all of equal volume; this was figured long ago by Leuwenhoek.

These circular fibres are disposed in very thick bundles, together with organic muscular fibres, which in some places are very abundant; in the umbilical vein, there are a good many; also in the vena portarum, in the sinuses of the brain, and in the rachidian veins; there are also more in the superficial than in the deep veins of a limb, as in the arm, for instance.

The fourth tunic, called the *adventitious*, is very variable in thickness; in the pia mater it is almost impossible to see it. It is formed of cellular tissue, and of elastic fibres of the dartoid variety, intermingled in all directions, not at all regularly. This tunic is very vascular. It is really a particular tunic, belonging to the veins.

In the tunics of the veins, the distinction is more difficult than in the arteries; they are distinguished as much by the *direction* of the fibres as by anything else. Again, in the vena cava, in the fourth tunic, you find also muscular fibres of organic life. M. Bernard has also shown them from the auricle to the renal vein. They exist in the veins of the liver, not in a layer, but in fasciculi, somewhat separated from each other. In the veins, all the tunics, except the internal, are vascular.

The veins present no morbid alterations similar to those of the arteries, but they can become inflamed. When the tissues are vascular you observe lesions different from those in tissues which are not; the lesions of the veins are entirely acci-

dental, they do not come from age. Inflammation of the veins being described everywhere, it is not necessary to do so here.

It may be well, however, to say a word of varices and of hemorrhoids. Their exterior aspect is owing chiefly to the blood contained, which sometimes forms clots obliterating them; the change in appearance does not come from a change in the walls of the veins.

In varix, you find the *longitudinal* fibres almost gone, but the *circular*, and chiefly the elastic fibres, are hypertrophied; you see them in voluminous fasciculi, that are very often separated from each other.

The modifications in the veins are principally caused by the circulation; they are rather a *consequence* than a *cause*, and it is important to make this distinction, for authors generally repeat just the contrary.

Note C.

ON THE INTIMATE STRUCTURE OF SOME OF THE PARENCHYMATOUS ORGANS, MENTIONED BY M. BERNARD, AS MORE PARTICULARLY CONNECTED WITH THE CIRCULATION.

Of the constituents of the body, M. Robin makes two groups, the *tissues*, properly so called, having a fundamental element, and the *parenchymes*, having about an equal proportion of the anatomical elements. It is the epithelium that characterizes the latter, for it has special properties.

This epithelium lines the tubes, which are contained in the parenchymes. These tubes have no wall, properly speaking; it is very thin, of amorphous matter, very difficult to distinguish; it is called by English writers *basement membrane.*

The parenchymes are divided into the glandular and those not glandular; in the former are the thyroid gland, the mammary, the sudoriparous glands, &c.,—in the latter, the testicle, the ovary, the kidney, and the lungs.

Some who call the kidney a gland, laugh at others who call the lungs one, but no one can laugh at the other. It is physiology that distinguishes them, just as it determines a nerve to be sensitive or motor.

The glandular parenchymes are those, that

fabricate some special proximate principle, as the salivary, ptyalin; the pancreas, pancreatin; the liver, the choleate of soda; the mammary gland, milk-sugar, &c.

The others fabricate nothing; in the kidneys substances are only thrown out, and the lungs are for gases what the kidneys are for solids and liquids. In the ovary and testicle, a particular anatomical element is formed, but it is not at all like a secretion, as of bile or milk; there is a body born *de toutes pièces*, from a liquid there.

Their anatomical differences are principally in the distribution of the bloodvessels, at least for the lungs and kidneys there is something special. In the glandular parenchymes the meshes of the vessels have nothing peculiar, being just as they are in cellular tissue generally. In the ovary and testicle, there is something very special in the walls.

The glandular parenchymes are of three kinds. First, the follicular, of two varieties, the simple and the rolled. The second has also two varieties, those *en grappes simples*, and those *en grappes composées*.

The third kind comprises those with no excretory duct: the spleen, the thymus, the thyroid, the glands of Peyer, the supra-renal capsules, and the lymphatic ganglions.

The *liver* is a glandular parenchyme, of the second kind, *en grappes composées*.

It may be well, on account of the false state-

ments in books, which maintain that a gland is simply a mucous membrane turned in upon itself, to say a few words upon the excretory ducts of glands.

Between the secreting cul-de-sac of a gland, and the surface of the mucous membrane, upon which the secretion is poured, is a duct which differs in structure from both. *Every part of the body that has a different function, has a different structure.* This excretory duct has a middle tunic, at least the half of which is composed of fasciculi of organic-muscular fibres, and the other half of cellular tissue, being more or less firm, as one or the other predominates. On the outside of this tunic is a layer of cellular tissue, and on the inside is a true mucous membrane, having an epithelium, and very thin; sometimes it is but a layer of amorphous matter; sometimes there is some cellular tissue. This epithelium is always different from that in the culs-de-sac of the gland. The cul-de-sac has no mucous membrane; the excretory duct has, but it ceases at the secretory portion of the gland, just where the epithelium changes. The different parts of a gland can thus be distinguished by the microscope.

The anatomical elements and their arrangement in the liver, are as follows:—

The epithelium,—the hepatic epithelium, properly speaking; that of the secretory portion, not that lining the excretory ducts,—is pave-

ment. The cells are generally polygonal, regularly and irregularly so, and sometimes spherical. They are finely granular, and contain sometimes an oval nucleus, sometimes two, and almost always a nucleolus.

In fatty liver, you find drops of oil in the epithelial cells, more or less abundant according to the subject, and this is the cause of the affection. In such cases the nuclei may be pushed to the side, or may have completely disappeared. This is all that is found in this affection.

M. Robin relates a curious case, in which the liver, very much enlarged, extending up to the fourth rib, was tapped under the supposition that the affection was a pleuritic effusion. A basinful of blood was drawn off, to the amazement of the operator; and M. Robin being consulted, found it to contain epithelial cells of the liver. He has known himself of three similar cases, and they are interesting in another view, as showing how physical signs may deceive.

Besides a thin layer of epithelial cells, that forms the walls of the secretory tubes, nowhere so thin, nowhere so soft, as in this organ, they are disposed in culs-de-sac, quite short and contiguous to each other, the acini being arranged like bundles of grapes. In the liver the secretory tubes touch; you cannot isolate them as you can in the mammary gland, and this is owing to there being no cellular tissue between them.

The cells on the internal surface of the culs-de-sac are very thick, so that scarcely any inside canal is left. This pavement-epithelium continues into the duct, until it has a greater diameter than the 0·10 of a millimetre. When the diameter is greater than that, from the uniting together of several ducts, the epithelium becomes columnar with vibratile cilia; from secretory the duct has become excretory.

The vessels going to the liver, are the hepatic artery and the vena portarum. The hepatic artery gives nothing to the acini; it only goes as far as the capsule of Glisson, or the cellular tissue, which stops where the columnar epithelium does.

The vena portarum is distributed in ramifications around the acini. The acinus is covered with longitudinal meshes, very narrow and very near to each other; the capillaries touching each other like the fingers of a closed hand, the appearance is very peculiar.*

These ramifications give rise to the small hepatic veins, and these uniting form the intralobular vein, interposed between several acini.

The liver is very rich in lymphatics, a network covering each acinus, just as the portal vein does. When bile or mercury is thrown into the substance of the liver, the culs-de-sac being very

* In the liver, the vessel divides *suddenly, all at once,* into a number of small branches. This is true likewise of the thyroid, and of all glands that have no excretory ducts. It is singular when connected with one function of the liver, the formation of sugar, which is thrown at once into the blood.

soft, they break, and the lymphatics are injected. When thus injected they are seen to accompany the vena portarum, the hepatic artery, and the biliary duct, they are around them in the capsule of Glisson, and form what is called, the plexus vaginalis. These lymphatics, thus injected by the rupture of the tissue, have been mistaken for excretory ducts.

The *pancreas* is another gland of the same kind as the liver; *en grappes composées*. It is remarkable for the very small quantity of cellular tissue it contains, on account of which it is very friable. Between the acini are always some adipose vesicles. The glandular culs-de-sac are very short and rounded, so that each one empties itself almost directly into the duct. In the glands of Brunner it is different; there the culs-de-sac are very long and separated from each other; they do not touch each other at all, and are very voluminous; they offer, moreover, a kind of dilatations, resembling varicosities in their length, and protuberances at their ends. The walls of the culs-de-sac of the pancreas are very thin. The epithelium is pavement, containing a spherical nucleus, and sometimes two, a very rare thing, and one chiefly observed here, in the hepatic cells, and in those of the kidney. The epithelial cell is quite large, soft, and friable, and it is therefore very easy to set the nucleus free.

Of all the glands, the epithelium is the most granular, and the central canal also, that is to

say, the secreted liquid it contains, is the most granular. This renders the study of this gland very difficult, and distinguishes it at once from any other.

The *spleen* is one of the glands having no excretory duct. They are characterized by the presence of closed vesicles, which vary in diameter, and also in the nature of their walls. These closed vesicles are simply accumulated, so as to take a form somewhat polyhedric, and between them are cellular tissue and some fibro-plastic elements. The thymus has very little cellular tissue, as also the supra-renal capsules, hence they are the softest. The manner in which the arteries branch off in this order of glands, was mentioned when speaking of the liver.

In the spleen there exists a complication to the fundamental structure of these glands; the closed vesicles are separated by venous dilatations, to which they are adherent, and whose walls are very thin. This renders its structure complex, and makes it not only a secreting organ, but also a diverticulum of the circulatory system. Its blood contains white globules, like the rest of the portal blood. What is called the *splenic mud* does not come from the veins, but from the closed vesicles.

The closed vesicles of the spleen have a peculiar disposition; the epithelium is very close and thick on their internal surface, but the capillaries traverse it. They have a fibrous wall, holding a

solid mass of epithelium, and the vessels traverse it. The epithelium is nuclear. These closed vesicles are the corpuscles of Malpighi; they adhere, as was said, to the veins, and to each goes a small artery.

In the walls of the spleen are many organic muscular fibres.

The structure of the *lymphatic glands* is complex. The manner in which the ramified lymphatics are related to the other elements of a ganglion, is not yet well understood. The elements are fibres of cellular tissue, with much fibro-plastic and a great deal of amorphous matter interposed to vesicles.

In syphilitic affections, each vesicle increases in volume, but the enlargement of the gland is chiefly owing to the augmentation in quantity of these other elements.

These closed vesicles are small and almost always irregularly *bossellées* on the surface, on which account their form is never regular. Their wall is granular and striated, very soft, and easy to crush. In their interior is found a serous liquid, which is in but small proportion, compared to the epithelium contained.

This epithelium is normally of different kinds; you find the pavement and the nuclear, the latter being smaller, but more numerous.

The pavement epithelial cells are generally elongated, and with edges rounder than in the

mucous tissues, and their nucleus is quite large, with a very evident nucleolus.

The nuclear epithelial cells are spherical, of a dark color, and a diameter of ·008 to ·009 millimetres, holding granulations quite voluminous in the centre, but smaller on the circumference. They are not affected by acetic acid, and this last fact is important, for it serves to distinguish them from pus-globules, for which they have been taken by some persons. The absorption of pus has been thought to be proved, by the extraction of some of these cells, mistaken for pus-globules, from a gland in the neighborhood of an abscess, by means of a trochar.

It is very important to study the epithelial cells of the lymphatic glands, for they are often attacked after epithelial tumors of the skin and mucous tissues, corresponding to them; as the sub-maxillary, when of the mouth; those in the groin, when of the prepuce. These epidermic tumors are of pavement-epithelium, often containing epidermic globules.

Most surgeons would prove the identity of cancer and of epithelial tumors by the fact, that in both the ganglions are affected. The argument, however, is a bad one. It is more frequent perhaps to have the ganglions affected in epidermic tumors than in cancerous; and again, many cases in which the ganglions are affected are called cancerous when they are not so.

It has been thought that in these cases there

must have been a material transport; but this is most certainly not correct; "the idea is a ridiculous one, if there ever was one so." Anatomy shows us here nuclear and pavement-epithelial cells; now, why is it astonishing to find the same diseases, as in other parts, resembling these in structure? You have analogy of structure, of nutrition, and of disease. He who knows the structure of the ganglions is astonished not to find them more often affected in epithelial tumors.

The study of the diseases of these glands, with no excretory duct, is not so satisfactory as that of the others, for we do not know their function. These glands are for the circulatory system, and we do not yet know this system. The blood of the arm proves nothing for that of the rest of the body. In typhoid fever, the spleen, and the lymphatic ganglions are affected, and here researches should be made.

The *lungs* and the *kidneys*, the two organs that remain to be examined, belong to the parenchymes which are not glandular.

In the *lungs* are two distinct parts, the bronchi and the canaliculi. In the bronchial tubes you find a mucous membrance, and vascular ramifications having nothing peculiar; in continuity with these tubes, but different in structure, are the canaliculi.

The bronchi have a vibratile or ciliated-epithelium; the canaliculi have a pavement-epithelium

with quite large nuclei: they are thus easily distinguished.

Under the epithelium in the canaliculi you find a capillary network, so very close, that nothing can be introduced into the interior without traversing them; they touch as the fingers of a closed hand, leaving no visible interval. These canaliculi present projections, and terminate in culs-de-sac. Outside of them is found yellow elastic tissue, disposed in fasciculi, superposed to each other, and forming a canal around the canaliculi. This renders the lungs very elastic. Mixed with the elastic fibres are found some fibro-plastic elements.

The canaliculi dilated cause one form of emphysema; when they are ruptured you have the other, or emphysema properly speaking.

Three kinds of alterations are described in the lungs as tubercles.

First, what really are tubercles.

Secondly, small granulations, that can be as large as the head of a pin or a pea, and which are epithelial tumors. They are found generally in persons five or six years of age; they form whitish grains, hard, and projecting upon the surface, when an incision is practised. They contain chiefly pavement-epithelium, with some columnar.

Thirdly, what is called infiltrated tubercle, the gray granulations. They are opaque, or, at times, demi-transparent. The microscope shows some epithelial cells, some fibro-plastic elements, and much granular amorphous matter, to which their

color is chiefly owing. They contain, besides, the small spherical corpuscles, rounded, of a diameter of 0·005 to 0·006 millimetres, found so abundantly in the chalazion. These bodies form a distinct element, but their description has not yet been given, for they have been very little studied. This third alteration of the lungs is very frequent, and in the greater part of the cases of acute phthisis, you find no tubercle, only these granulations. In such cases you *almost never* find tubercle. Whether inflammation brings them, or they bring inflammation, is not known. The pathological anatomy of the lungs must then be taken up again. This subject is one of such vast importance, that although it is very indirectly connected with the circulation, some account of tubercles will be given in a note, which, on account of its length and its little connection with the rest, it is thought best to place after the description of the kidney.

The structure of the *kidney* is simple, epithelium lining uriniferous, or uriniparous, tubes. The epithelium is pavement or nuclear; in many tubes in the tubular portion of the organ, you only find the nuclear; in the tubes of the cortical portion you find chiefly pavement. The uriniparous tubes are composed of a completely homogeneous substance, like glass, without granules. They open on the projections on the internal surface of the organ; for some distance they are parallel to each other, forming the tubular portion, and when at some depth, they become very flexuous, twisted and folded, forming

the cortical portion. The tubes are the same everywhere, but their direction changes their appearance. They are lined with an epithelium, as said before, and filled with a granular matter; their contents can be found at times forming cylinders, as in cases of typhoid fever, &c. What is called the Malpighian body, is a small body, of a diameter of 0·10 of a millimetre, situated very near the termination of the tube in a cul-de-sac. It is nothing at all but a dilatation of the tube, lined by the epithelium, into which an artery goes, that rolls round on itself, and comes out a vein. Sometimes two tubes go to one *glomérule.*

In the tubular portion of the kidney, the capillaries are parallel to the tubes; in the cortical, they run in all directions, about indifferently.

In Bright's disease, the yellow spots are owing to fatty granulations in the cells of the epithelium, which generally become two or three times larger than natural, and quite often the tubes become dilated. The black spots that are met with come from effusions of blood in the tubes, the hematin remaining as amorphous matter.

You often find in the kidney, above all in cases of inflammation of that organ, the same granulations spoken of as found in the lungs. They are more whitish, but their structure is the same.

NOTE ON TUBERCLE.

The study of the corpuscles of tubercle is simple and brief, as far as they alone are concerned. They are small, however, and are always accompanied with much granular matter, which is often, particularly in the kidneys, more abundant than the corpuscles; for these reasons their study is very difficult, and they are made by some authors to be but a heap of granulations.

These corpuscles are bodies slightly irregular on the surface, and containing no nucleus. They are polyhedric, either of equal diameters, or elongated; when elongated, they are not flattened. Their borders are dentated, and in the centre are many granulations, contained in an amorphous mass. Their diameter is from 0·007 to 0·009 millimetres, very rarely 0·010; that is to say, though such almost always exist in a specimen, they are few in number. They are very rarely rounded; when nearly so you find them slightly dentated. Their contour is well marked, quite dark. Water has no action upon them; acetic acid pales but does not dissolve them: this it is important to note, for it is easy thus to distinguish them from nuclei of any kind, for all nuclei except those of cancer are rendered darker by it. The corpuscle contains no nucleus itself, and thus can easily be distinguished from concrete pus-globules, in which acetic acid shows at once the nuclei.

In addition to this, the corpuscle of tubercle is much less paled.

Their structure is simple, an amorphous matter sprinkled with granulations. In some are found fatty granulations, that could be taken for nuclei.

Tuberculous Tissue.—The external aspect of this tissue it is not necessary to describe, except that the color would be insisted upon. A *gray demi-transparent* tubercle has been described, but tubercle is *always* yellow. This color is characteristic of tubercle; it is the most fixed of its external characters. When you see gray granulations, you can say at once, it is not tubercle; when they are yellow, be on your guard, for they may be.

The yellow color may come from fat, and not be from tubercle: concrete pus may have a yellow color.

Internally, are seen the corpuscles, molecular granulations, quite often fatty granulations; and amorphous matter, generally in very great proportion, uniting all. Never are any vessels found; this was pointed out long ago, and has been confirmed by general anatomy. Some vessels may be enclosed in the tissue, but none are proper to it.

What is called the infiltrated tubercle of bones, in the neighborhood of white swellings, is always found to be concrete pus, and the same thing is true also of the pretended circumscribed tubercle of bones. The serum of the pus has been absorbed. Concrete pus is less yellow, less homogeneous in aspect than tubercle.

What are often called tubercles of the meninges are certain *plâques* of amorphous matter, sprinkled with fatty granulations, they are more transparent than the true tubercle of the meninges. What has been said while speaking of the lungs will also be remembered.

Tubercle is, in reality, the most fixed of all the anatomical elements; there is no variety, it is ever the same.

Note D.

A report of the experiments made by M. Bernard is to be seen in the *Compte Rendu* of the Biological Society, for December, 1849. These experiments were first made in Germany by M. R. Wagner, who wished to see if the *cell-fibres* discovered by Kölliker, merited the name he had given them, of *muscular*.

If they be muscular, they must be contractile, and the tissues where they are found in sufficient quantity must be contractile. He, therefore, tried if the spleen, in whose tissue they are very numerous, could contract under the influence of galvanism. The spleen had long been known to be contractile. M. Dufermon has pointed out the singular contraction of that organ, under the influence of strychnia, and M. Wagner, by means of galvanic excitation, obtained unquestionable contractions.

By the invitation of M. Rayer, perpetual pre-

sident of that Society, M. Bernard procured two dogs, and aided by several of the members, made the following experiments.

One of the dogs was poisoned with strychnine, after his spleen had been laid bare, without injuring its vascular pedicle. The different dimensions of the organ were measured, and when the animal, seized with tetanic convulsions, was about to die, the measurements were repeated. Only a very slight diminution of volume was found, which might, moreover, have depended upon a diminution of the blood circulating in the organ, but it appeared evident to many of the assistants, that the surface of the spleen had changed in appearance, and from smooth had become *shagreened*, and that its edges had changed in form.

This experiment, as is seen, did not give very well-marked results. It must not, however, be concluded from it that the spleen is slightly or not at all contractile under the influence of strychnine; in fact, the spleen employed in this trial, presented pathological alterations.

The spleen of another dog was exposed, with the same precaution. The dimensions of the organ having been taken, the conductors of an energetic electro-magnetic apparatus were applied to its two extremities. After several minutes of excitation, the length of the spleen had diminished 2 or 3 centimetres. This experiment was repeated several times with an analogous result. When the current was made to pass in a transverse direction through the organ, an incontestable dimi-

nution of the breadth was also found. This done, the pedicle of the spleen was cut, and it was suspended by its large extremity to one of the conductors of the electro-magnetic apparatus; at more than twenty different attempts, and at every application of the other conductor on the small extremity of the spleen, a very manifest movement of ascension and of torsion of the organ were seen, manifest above all, in the neighborhood of this small extremity.

These *muscles of organic life*, to the presence of which the spleen owes its contractibility, are essentially different from the muscles of animal life; there is no transition between them. Their property of contraction is not similar to that of the others; they contract very slowly.

They are met with in very different parts: in the excretory ducts, in the walls of the bladder, the uterus, the vesicle of the bile, and the digestive tube. Again, layers of muscular fibres are found under a certain number of mucous tissues, under the vaginal, that of the stomach and of the conjunctiva. They are also found everywhere under the skin, everywhere where there is no subcutaneous muscle of animal life, in quite narrow fasciculi. In animals having a beard, as the cat, there is a true muscle of animal life, extending to the pilous bulbs from the deep surface of the derm.

This must be insisted upon, because all the

above-mentioned parts have been called contractile, and the cellular tissue has been said to give them that property. Everywhere where the cellular tissue is said to be contractile, there are muscles of organic life. Where the mucous tissue is called contractile, there are fasciculi of organic muscular fibres, not large enough to be seen by the naked eye.

To explain the movements of the Fallopian tubes, it is said that the muscular fibres from the uterus are continued there. The Fallopian tube is always a distinct organ from the uterus, as well when the uterus is bifid, as when simple; it does not follow a proportional development, and even by simple dissection, its tissue can be most clearly determined to be distinct. The tube has longitudinal fibres of organic life, whose diameter is so small as to render them always invisible to the naked eye; there are some also oblique, but none circular.

The organic muscular fibres are fusiform fibres, but their volume is so great, that they can never be confounded with other anatomical elements, having the same form.

Their length is from 0·070 to 0·300 millimetres; the largest may be even 1 millimetre.

Their breadth is 0·010 to 0·025 and may be even greater; in the empty uterus it is only 0·007 or 0·008. Their thickness is only from 0·002 to 0·003. They are flattened, transparent, and very pale, yet their edges are very clearly defined.

Water does not attack them, but acetic acid does very rapidly, acting as it does upon cellular tissue.

Although very transparent, yet there are many granulations, chiefly about the nucleus.

The fibres in the intestines very often want these granulations.

They have one or two very long nuclei; when two, they generally touch each other, but they can be separated.

These nuclei are *very elongated*, and may be bent like an S. They are not attacked by acetic acid, and sometimes have a nucleolus; they are much longer and more narrow than those of the fibro-plastic elements. They are very important to know, for when the organic muscular fibres are mixed with cellular tissue, you do not at first see them; their existence can only be well determined after the addition of acetic acid. This renders transparent the body of the muscle, and the whole of the cellular tissue, and leaves these peculiar nuclei, which are then always disposed in series that are very characteristic.

The extremities of the fibres often present swellings or nodosities, and you see transparent parts between others more opaque. These are seen particularly in the œsophagus, in the bladder, in the large and small intestine, and in the excretory ducts of the glands.

These fibres are generally disposed in fasciculi, yet they have no perimysium. They are thus disposed principally in the Fallopian tube, in the

eircular layer of the œsophagus, and in the vas deferens of the tesiele. In the walls of the intestine they are much less closely united, and also in the bladder; in order to find them well isolated, they must be therefore sought in the intestines, in the bladder, or in the uterus.

The fasciculi are always parallel to each other, sometimes in layers, longitudinal, or oblique, or vertical. What to the naked eye, in the intestines, appcars a muscle, are bundles of these fasciculi; under the skin are found fasciculi having a diameter of 0·05 millimetres.

There are always some elastic fibres with them, which follow the direction of the fasciculus; in the bladder they are very abundant, but in the uterus, and in the Fallopian tube, there are very few. These elastic fibres play the part of the perimysium, or sareolemma, in the fasciculi of animal life. Cellular tissue is always found with them, even in the vas deferens. In the uterus the proportion is very great, and it varies in this organ, according to its eondition.

As the uterus develops, in pregnancy, the museular fibres are seen to augment much in length: a confirmation of the fact that the anatomical elements ean present variations, according to the region, and according to the condition of the organ, in which they exist. Again, in fibrous tumors of the uterus, there is always a great proportion of organic muscular fibres; about one-third or one-fourth of them is thus composed, and they are so much the less abundant as the tumor is

larger. In these tumors the fibres are larger than those in the uterus itself. They are slightly hypertrophied.

Note E.

In December, 1853, before the Biological Society, M. Bernard read a paper entitled "Experimental Researches on the Great Sympathetic, and especially on the Influence which the Section of this Nerve exercises on Animal Heat." As the *Compte Rendu* of the Society for that year has not yet been published, and the subject is one of the highest interest, an abstract of the paper is here given, taken from one of the very limited number of copies that were printed separately.

M. Bernard made these experiments, struck by the great number of contradictory facts existing in science relative to the influence of nervous lesions on the calorification of paralyzed parts. In some the increase, in others the diminution, of heat had been observed. He thought the reason of these diversities must be sought for in a specialty of influence of the different kinds of nerves. Here, then, it was necessary to examine successively the influence on the calorification, of the nerves of movement, the nerves of sensation, and those of the great sympathetic. Influenced by the very

ancient idea, that the great sympathetic, which accompanies especially the arterial vessels, must be the nerve which presides over the phenomena of the organic changes taking place in the living tissues, M. Bernard thought that its section, by causing the atony of the vessels and the slowness or the abolition of the circulatory and nutritive phenomena, would probably be attended with the cooling of the parts. To make the experiment, he chose a rabbit, because in this animal the cervical cord, which goes to the head, running from one ganglion to the other, is easily found and is very distinct from the pneumogastric. The result was very different from what he expected. In place of a lowering of the temperature, it was very much elevated in all the corresponding side of the head. His hypothesis thus vanished before the reality, but it had put him upon the trace of a new fact, which remained an acquisition to science; this fact was to be studied, to be isolated, and have its signification given to it among the phenomena relating to the history of the sympathetic nervous system. This section of the nervous cord had often been made, but the phenomena connected with it, as given, are contraction of the pupil and redness of the conjunctiva; the retraction of the ocular globe into the depth of the orbits; the contraction of the palpebral opening, and at the same time a deformity of the opening, which becomes more elliptic, and more oblong transversely; the flattening of the cornea, and the consecutive dimi-

nution of the ocular globe. M. Bernard is the first who indicated a modification of the circulation coinciding with a great augmentation of the heat and even of the sensibility of the parts.

Nerve of sensation.—M. Bernard has often repeated the section of the fifth pair, and has always seen the operation followed by a lowering of the temperature on the corresponding side of the head. But if, then, the section of the sympathetic was practised, the phenomena of calorification took place just as ever, and independently of the lesions which the paralysis of the fifth pair produced.

Nerve of movement.—He first cut the facial, a short distance from its exit from the stylo-mastoid foramen, by penetrating into the tympanum with a sharp stylet. The operation was followed by the ordinary symptoms of paralysis of movement, and in addition, he always found that side to become, and to remain, hotter than the other.

But by other experiments he came to the conclusion, that when the facial nerve alone was divided, there was, on the contrary, a diminution of the temperature. In these other experiments he cut the fibres which give rise to the facial nerve, situated in the medulla oblongula. In cutting the nerve after its passage through the base of the cranium, you cut in addition some fibres of the sympathetic that are united to it.

The section of the cervical filament of the great sympathetic, and above all the extirpation of the superior cervical ganglion bring about immedi-

ately and simultaneously, an augmentation of heat, and a very great vascular turgescence in the ear, and all the corresponding side of the head. The arteries, more full, seem to beat with more force, the circulation is rendered more active, and the absorption of toxic or other substances, introduced in equal quantity in the subcutaneous cellular tissue of the face, or at the base of the ear, is more rapid.

There are without any doubt intimate relations, that no one can fail to recognize, between the phenomena of calorification and of vascularization of the parts of the body. But for this must it be said, that in the case at present under consideration, the augmentation of the heat of the ear and of the side of the face should be attributed simply and purely to the fact, that the mass of blood circulating there, having become more considerable, is less easily cooled, and causes the part to seem more warm? This entirely mechanical explanation, which must at first present itself to the mind, would be insufficient to explain those differences of 6° or 7° Centigrade that sometimes exist between the two sides of the face. M. Bernard has been, moreover, induced to reject this explanation, because that very often the vascularization is seen to diminish considerably the day after the operation, although the ear has not sensibly varied in temperature. Among a very large number of experiments of this kind, which he has been able to observe, he cites but one, in order to give a more

exact idea of this fact. On a large rabbit, vigorous, and well fed, he extirpated the superior cervical ganglion of the right side. The operation was made in December, and the surrounding temperature was low; before the operation, the temperature taken in the two ears was :—

For the right ear, ...	33°
For the left ear, ...	33°

Immediately after the extirpation of the ganglion, the right ear became very vascular and very warm, while that of the opposite side had not sensibly changed in appearance; in a quarter of an hour the temperature of the two ears was taken and found to be :—

For the right ear, ...	39°
For the left ear, ...	33°

Thus in a quarter of an hour, the heat of the ear and of the face had risen six degrees, Centigrade. The phenomenon had not yet reached its maximum, for one hour after the thermometer stood at 40°. The animal was left until the next day, when he was again subjected to observation. The right ear was much less turgescent than the previous evening, the arteries were considerably diminished in calibre, and very great attention was necessary in order to perceive the difference in the two ears. It was only the very small vascular ramifications or the capillaries, that remained more visible, and more numerous (to the sight) in

the right ear. The hand, however, perceived very manifestly a great difference of temperature between the two sides of the head, and the thermometer in the two ears, gave :—

For the right, ...	37°
For the left, ...	30·5°

This experiment shows that the enormous vascular turgescence, and the accumulation of a great quantity of blood, which immediately follow the operation, can considerably diminish without leading to a notable diminution of temperature. However, as was just said, the capillary circulation remains always more visible in the hotter ear. It must not be concluded from this, that the temperature must always be higher when the capillary vessels are more visible. Following the section of the fifth pair, as is well known, the conjunctiva becomes very red, and the capillaries there, as well as in other parts of the face, become very visible, and yet there is always a diminution of temperature in these cases. If to this it be objected, that after the section of the fifth pair there is an obstruction of the vessels, which hinders the circulation and causes the cooling, it would be answered by the experiment cited elsewhere, namely, that in these cases the section of the sympathetic causes at once the calorification to appear in the tissues where the vascular turgescence already existed, but with cooling.

This calorifying action of the sympathetic, even

on parts where the course of the blood is hindered and diminished, will be rendered still more evident by the following experiment.

On a rabbit, full grown and in good health, he tied the two vascular venous trunks of each ear. After this operation the veins were dilated and became gorged with the stagnating blood; and at the end of three-quarters of an hour the two ears were manifestly cooled by the stasis of the blood. He then made the section of the cervical filament of the right side, and at once the corresponding ear became hotter. It is impossible to explain this calorification by the accumulation of blood, which before had been producing an inverse phenomenon, the cooling that continued to be observed all the time in the other ear. He then performed the ligature of the artery so as to imprison the blood in the ear; the temperature diminished a little, but remained always higher than in the opposite ear.

When, in place of the primitive ligature of the veins, that of the arteries was practised, the parts were also cooled, but by an inverse mechanism. In the first case the cooling is the consequence of the impossibility of the renewal of the blood, and in the second, it is the result of its absence. We saw that in resecting the sympathetic, after the ligature of the veins, the calorification can be produced, which does not take place when it is performed after the exact ligature of the arteries alone. All this simply goes to show, that if the

phenomenon of calorification cannot be produced in parts whose vessels are completely empty of blood, it can, on the contrary, take place in parts where the blood is stagnating, and independently of its rapid renewal. This proves, moreover, this proposition, that in the dog or rabbit, when the calorification of one of the sides of the head is very much developed, under the influence of the extirpation of the sympathetic filament, if you diminish the afflux or the renewal of the blood, by the ligature of the carotid artery of the corresponding side, you see nevertheless the heat of the parts to remain always more elevated than that of the opposite side.

After these experiments, it is not, then, possible to explain the warming of the parts by a pretended paralysis of the arteries, which by reason of a passive enlargement would allow a greater quantity of blood to circulate,—*pretended* paralysis, because, in effect, it is rather in the state of theory than of demonstrated fact. If the section of the sympathetic paralyzes the contractile fibres of the arteries, at the instant of the operation a sudden enlargement of the artery should be seen, and it is always just the contrary that is observed. On making the section of the cervical filament in rabbits, where it is very near the carotid, M. Bernard has always seen the artery to become considerably narrower, immediately after the section or the tearing of the filament. If at a later period this artery and its branches become larger, it is be-

cause they are distended by an afflux of blood, that takes place in the corresponding parts; but far from being the cause of the more active circulation, the enlargement of the arteries is, on the contrary, only the effect of it. Moreover, if this paralysis of the arteries really existed, should not their dilatation under the influence of the heart's impulsion go on, always augmenting, from the moment of the operation? Nothing of the kind occurs, since we have seen, on the contrary, that the day after the section, the vascularization has ordinarily much diminished, and the arteries have returned to their former size, although the animal heat is always notably augmented.

In a word, the circulatory phenomenon which follows the section of the sympathetic nerve is active and not passive; it is of the same nature as the turgescence which, as M. Bernard has elsewhere shown, takes place in a secretory organ, that from a state of repose, or of feeble *functioning*, passes to a state of very active *functioning;* it approaches, moreover, the afflux of blood and the augmentation of sensibility, that take place around a recent wound, or in the neighborhood of a foreign body sojourning in the living tissues.

M. Bernard does not occupy himself here with the explanation of these phenomena, to which he will soon have occasion to return. It suffices to say, that although in all the cases you see the vessels more gorged with blood, and the arteries beating with greater force, it cannot come to the mind

of any one to suppose these phenomena to be caused by pure and simple paralysis of the arteries.

To resume. The following propositions seem clearly to result from the experiments he made :—

First. The section of the nerves of sensation, besides the abolition of sensation, produces the diminution of the temperature of the parts.

Secondly. That of the nerves of motion, gives rise equally to a cooling of the paralyzed parts.

Thirdly. The destruction of the sympathetic nerve, which produces neither the immobility of the muscles, nor the loss of sensibility, leads to a constant and very considerable augmentation of temperature.

Fourthly. If a mixed nerve be cut, a nervous trunk enclosing at once nerves of sensation, of movement, and some filaments of the great sympathetic, the three effects are had, united, to wit: paralysis of movement, paralysis of sensation, and exaltation of heat. This is obtained by the section of the sciatic nerve, for example. It will, however, be understood that the calorification in this last case must be slightly less pronounced, because it is then counterbalanced by the diminution determined simultaneously by the paralysis of the nerves of sensation and of motion.

Fifthly. M. Bernard believes, then, to have with reason established the fact, that this increase of heat is the special result of the section of the sympathetic nerve.

This elevation of temperature commences instantaneously. The ablation of the superior cervical ganglion is followed by the same effects as the section of the cord, but these effects are always more rapid, more intense, and more durable. After the section of the cord, these effects in the rabbit lasted only 15 or 18 days, in the dog, six weeks or two months; after the ablation of the ganglion they can be considered indefinite. In a dog whose superior cervical ganglion had been extirpated, they were still very intense at the end of a year and a half.

This difference of 4° or 5° is remarkable as the difference between the two sides of the face, but if the temperature of the cut side be compared with that of the central parts of the body, it is found to be about the same. M. Bernard, however, has often determined that the heat was 40°, while the normal temperature of the central parts in the animal was 38° or 39°. When the animal was placed in a hot place, the warmer side did not become more heated, while the opposite did, so that you could not distinguish the side operated upon. When in a cold place, the normal side cooled much quicker than the opposite.

When the animals were in good health, no œdema, nor any morbid trouble that could be attached to what is called inflammation, were ever observed in the side where the parts were so much warmer.

When the cut end was galvanized, in a dog, all

the phenomena disappeared and were even exaggerated in an inverse sense. It is impossible, as has been said, to cut the sympathetic alone in the dog, because it is intimately united to the trunk of the par vagum; but this nerve has no part in the phenomenon of calorification, as is proved by the same experiment, giving the same results, in the rabbit, where the section of the sympathetic can be made alone. A dog was chosen in this case, because the more considerable volume of the nerve, allows more easily of its galvanization.

When the animal was put under the influence of chloroform, the heat of the cut side was diminished, and that of the other increased.

M. Bernard has also practised the extirpation of the ganglions and the section of the filaments of the sympathetic in the thorax and abdomen, but he gives no account in this paper of these experiments, because they were made with other objects in view. He merely says of them that they have been followed by the same vascular and calorific effects as those made in the neck.

In conclusion, M. Bernard says: "I have only wished in this work to establish one point in the very complex history of the sympathetic, to wit: that the section of the filaments or of the ganglions belonging to this nerve, has constantly the privilege of augmenting the calorification of the parts to which it is distributed. These phenomena of calorification, which are produced by acting on the sympathetic, are in reality only the exaggera-

tion of those that take place in the production of animal heat. In giving the means of increasing the calorific acts, and of localizing them in the exterior parts, easy to observe, I have had the thought of rendering more accessible to our means of investigation, the study of this important function, still so little known, but which could not be sought elsewhere than in the greater or less activity of the chemical metamorphoses, which the blood undergoes in the living tissues under the special influence of the nervous system."

THE END.